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16. Abstract

The purpose of this project was to identify, from existing research on warning, regulatory, and symbol signs, where deficiencies in motorists' understanding may pose safety or operational problems and to define acceptable levels of motorists' comprehension. The study developed alternative designs to remedy the identified deficiencies. These proposed alternatives were laboratory tested, and final sign designs were evaluated in a simulated highway environment. The results of the simulator evaluation were verified in closed field tests.

This volume, the second of three, is a technical report which documents all the work conducted under this project. The first volume is an executive summary. The third volume is the appendices to the technical report.

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CHAPTER 1
INTRODUCTION AND BACKGROUND

Signs used to regulate, warn, and guide traffic have long been one of the standard means of communicating to the driver. Recently, however, there has been evidence that the system of regulatory, warning, and symbol signs currently in use is not well understood by the motoring public. Although there is a wide variation of opinion about the magnitude and severity of this problem, a detailed study of motorists' comprehension of regulatory, warning, and symbol signs is warranted. This report presents the results of that study, which set forth new sign design guidelines and comprehension criteria, and recommends specific changes to the Manual on Uniform Traffic Control Devices (MUTCD).

The purpose of this project is to identify, from existing research on warning, regulatory, and symbol signs, where deficiencies in motorists' understanding may pose safety or operational problems and to define acceptable levels of motorist comprehension. The study developed alternative designs to remedy the identified deficiencies. These proposed alternatives were laboratory tested, and final sign designs were tested in a simulated highway environment. The results of the simulator testing were verified in closed field tests.

To achieve the project goals, the following objectives were identified:

- Identify existing regulatory, warning, and symbol signs which exhibit motorist comprehension problems.
- Develop criteria for determining acceptable motorist comprehension of these signs.

- Develop remedies for those signs identified as poor performers.
- Evaluate the proposed remedies in laboratory and simulator tests.
- Field validate the final designs under actual highway conditions.
- Recommend new or modified design specifications for replacement signs.

The work done to accomplish the objectives is documented in three volumes. Volume I is an executive summary of the entire project. Volume II is a technical research report which details specific elements of the work done for this project. Volume III is the appendices to the technical report.

CHAPTER 2
STATE-OF-THE-ART REVIEW

This chapter includes a comprehensive review of the research literature, as well as documentation of an effort to tap other information sources about the motorist sign comprehension problem. Knowledgeable transportation professionals were contacted to obtain any information they might have regarding this problem. A review of tort liability cases involving highway signing was conducted to see if any incidence of problem signing showed up in the court records. The purpose of these activities was to estab-lish an information base which would be used to identify signing with comprehension deficiencies. Therefore, the work covered in this chapter consists of three subtasks: Literature Review, Professional Input, and Tort Liability Review.

LITERATURE REVIEW

The literature search gathered information regarding sign/symbol recognition, understanding, comprehension, or evaluation. The search covered both foreign and domestic sources, and covered unpublished materials as well.

Over 150 reports, papers, and articles were retrieved, reviewed, and abstracted. The abstracts highlighted the specific signs studied, the methodology used, and the specific results found about comprehension. The materials were grouped into four major subject areas: Literature Reviews and Historical Perspectives; Motorist Information Requirements and Sign Design Principles; Evaluation Techniques; and Sign Comprehension Criteria and Human Performance Testing. The salient items for each subject area are summarized below.

Literature Reviews and Historical Perspectives

A great amount of research has been done on highway user information, specifically in the area of traffic signing. This wealth of information has led to some fairly exhaustive treatments of the literature on previous research, as well as a chronicling of the history of traffic signs.

Dewar (1973) presented an excellent review of many facets of sign perception including visual and cognitive aspects, physical characteristics of signs, and testing methodologies. He also presented an updated abridged review of many of the same topics (Dewar, 1979). Trumbo, Serig, Hostetter, Gould, and Olsen (1978) provided a review of the traffic operations aspects and basic research regarding use of color, shape, brightness, and symbols in sign communication.

The historical development of traffic signs is covered in articles and reports by Markowitz, Dietrich, Lees, and Farman (1968); Zuniga (1969); Dewar (1979); and Wilson and Williams (1984). The information presented covers the progression from the British Highways Act of 1835, which was used to establish guidelines for the erection of directional posts, to the League of Nations and United Nations efforts to have international sign uniformity, as well as the U.S. system's growth from the 1927 Manual on Uniform Traffic Control Devices (MUTCD) to the 1978 edition of the MUTCD.

In tracing the growth of signing, one finds that there are two principal ways of communicating to the motorist. One is through the use of word messages and the other is through the use of symbols. Zuniga (1969) describes six different signing systems worldwide, each being either word message oriented, symbol oriented, or some combination of both. Today, the emphasis is on symbol

communication for all systems with the major variations being in the color and shape coding schemes.

Motorist Information Requirements and Sign Design Principles

In redesigning currently used signs or designing new signs, it is imperative to be aware of driver information needs and previously tested design principles. To date, the most extensive treatment of the subject was performed by King and Lunenfeld (1971). Using task analysis techniques, a study team of engineers and human factors specialists isolated and identified the information required by motorists to perform the driving task. The identified information needs were organized into functional groups, and these groups were analyzed to find the relationship among them and to formulate basic criteria which determine the most critical needs. They found that the critical elements of the driving task can be placed into a hierarchy. At one end of the scale (microperformance) are the tasks of tracking and speed control. Motorist response to situations occurring on the road fall in the middle of the hierarchy. The functions of choosing the travel route and pretrip planning fall at the other end of the scale (macroperformance). Motorist information needs can be ordered into a similar parallel hierarchy. They found that the primary need for information falls at the microperformance end of the scale, while the demand for information regarding macroperformance is less critical. Therefore, the highway information system should follow this basic principle. They also found driver expectancy to be a key factor in on-the-road performance.

Dealing with driver information needs in work zones, Hostetter, Crowley, Dauber, Pollack, and Levine (1982) focused in on microperformance tasks for the motorist in construction and maintenance areas. They evaluated traffic control devices on their likelihood to provide the driver with information about what he must do, where he must do it, and why he must do it.

The subject of sign design was dealt with by Markowitz et al. (1968). Through a series of laboratory and field studies, a thorough examination of the effectiveness of various sign elements (shape, arrows, borders, pictographs, colors, and colored shapes) and combinations of these elements as actual signs was conducted. The results of this work give an interesting set of "how to" and "how not to" design guidelines for signing. This gives the designer important information about what features of different elements of a sign are most easily recognized, but does not provide guidance about combining these elements into an easily comprehended sign.

Evaluation Techniques

The literature is full of references regarding evaluation techniques for traffic signs. These evaluation techniques are varied and in some instances it is difficult to ascertain what measures of effectiveness (MOEs) are being used.

One type of experiment measures the ability of subjects to detect the presence of a sign. In one study, a new sign was placed alongside the road and, at a distance further down the road, drivers were asked what was the last sign they had passed on the road (Johansson & Backlund, 1968; Hakkinen, 1970). In another experiment drivers were instructed to drive over a fixed route and name all the traffic signs which they saw (Summala & Naatanen, 1974). A similar test had drivers traversing a closed course at night and attempting to detect signs which were placed adjacent to artificial glare sources (Sator, 1981).

Beyond being able to detect the presence of a sign, some experiments have measured the distances at which the sign's symbolic or word message becomes visible to a test subject (Dewar & Ells, 1974). Some experiments have combined these two techniques

by having subjects tell when they can detect a sign and then tell when they can "read" the meassage on it as well (Sator, 1981).

The test technique which seems to be performed most frequently is one which measures how quickly a sign is recognized. The test checks the correct or incorrect recognition of a sign after the stimuli are presented for a brief period of time, or measures the amount of time it takes a subject to respond to the stimuli after they are exposed. The first of these techniques is referred to as glance legibility (Dewar & Ells, 1981) and the other is known as meaning latency (Hulbert, 1979). Dewar has used both of these techniques to test different characteristics of certain signs. In determining whether or not the "slash" prohibition obscures the symbol on traffic signs, a glance legibility evaluation was used (Dewar, 1976). An experiment to evaluate the relative recognition and classification of verbal and symbolic signs used a meaning latency technique (Ells & Dewar, 1979). Extensive testing of sign design elements such as color, shape, symbol, and borders has been conducted using a method of combining glance legibility techniques and signal detection theory (Markowitz et al., 1968). A similar test technique was used to evaluate proposed symbolic versions of word message signs which were to be included in the 1971 MUTCD (Dietrich & Markowitz, 1972).

A test technique which seems to address the matter of actual comprehension or understanding of meaning is one in which subjects are asked to "tell" what a sign means either through choosing the correct definition from a multiple choice test or defining the meaning in their own words in what is called an open-ended response. Jones (1972) used a mail survey to question a stratified sample of 322 Massachusettes drivers regarding their knowledge of symbol signs proposed for use in the 1971 MUTCD. The questions took the form of a "sentence completion" test. This technique provided what was essentially an open-ended response definition for each

sign tested. Koppa and Guseman (1978) conducted a survey of Texas drivers to assess the level of understanding of selected traffic control devices (TCDs). The survey instrument consisted of an album of pictures depicting 27 different traffic situations. The subjects were asked a question regarding each scene and instructed to choose one of the multiple choice answers which best answered the question. Not all of the questions asked the subjects to define the TCD in question. Some questions were concerned with the driving action response the motorist would make when confronted with the depicted situation (i.e., steering, speed control, braking, etc.). A follow-up study was done by Womack (1982). A sample of 96 Texas drivers was chosen for in-depth interviews. Using the results of the interviews, common misinterpretations were used as "multiple choice" answers for the follow-up survey.

The American Automobile Association (AAA) sponsored two studies which dealt with comprehension of TCDs. The first study presented the subjects with a driver's eye view of the roadway and selected TCDs using a motion picture test film (Hulbert, Beers, & Fowler, 1979). The subjects would view a scene and respond to a question about the TCD shown. The answers were given in a "multiple choice" format. The second test used the same method as the first but only three of the previously viewed scenes were used again as stimuli; the remaining scenes used TCDs which were not tested in the previous study (Hulbert & Fowler, 1980).

An evaluation of the conversion of Australian word message signs, and symbol signs with supplementary word messages, to symbol only forms was done using the level of comprehension associated with each sign as the primary measure of effectiveness (Johnson, 1980). An open-ended response technique was used to gauge initial levels of comprehension. Another Australian study

compared symbolic alternatives of an "at grade" railroad crossing warning sign using interpretability and legibility as the MOEs (Cole & Jacobs, 1981). The railroad warnings were shown along with 15 other regulatory and warning signs so that the exact nature of the study was not given to the subjects. The test results gave information regarding the legibility and interpretability of all 20 signs. The interpretability testing used a standard open-ended response technique. In the studies previously mentioned the subjects had adequate but not unlimited time to reply, while in this study the stimuli were presented for only 1.5 seconds. In a recent study of Wyoming drivers an open-ended response technique was used to evaluate six symbol signs (Wilson & Williams, 1984). The test results were significantly better when the sign was presented in an appropriate roadway scene as opposed to presentation of the sign only.

Some tests measure how easily the meaning of a sign is learned. One important variable in this type of test is the length of time between the learning of the sign's meaning and the subsequent testing of that knowledge. Brainard, Campbell, and Elkin (1961) tested the initial comprehension of 30 European traffic signs by American subjects. After telling the subjects the correct meaning of each sign, the subjects were immediately tested on the meaning of the signs. Since this test was more a recognition test than a true test of learnability, the results showed near 100% interpretability. Johnson (1980) used a similar test technique, but the time lag between the initial and secondary tests was one week. Mackie (1967) conducted a two-part study which attempted to gauge the progress made in learning symbolic traffic signs which had been newly introduced in the United Kingdom. Immediately after the introduction of the new signs, a survey was made to see how well the new signs were understood. The same survey was conducted a year later to assess what progress was made through learning and how the learning was accomplished.

Another method to evaluate the effectiveness of a TCD is to ascertain whether the motorist will make the correct action response to specific sign stimuli. Jones (1972) had test subjects complete sentences telling what they "must" or "must not" do when they encounter the test sign. Koppa and Guseman (1978) used a "multiple choice" response format to elicit action response information. Wilson and Williams (1984) used an "open-ended" approach.

One last evaluation technique considers the subjects preference for each test sign. Hoff (1971) used this technique to solicit driver opinions about different signs which would give motorists information about traffic conditions. Jones (1972), as part of a study in which general information about sign comprehension and action response was solicited, also asked for motorist's preference between the symbol sign being tested and the word message version of that sign. Hanscom (1981) also used preference data in a study of changeable message sign effectiveness at construction lane closures.

Sign Comprehension Criteria and Human Performance Testing

While there is much written about motorist comprehension of traffic signs, very little of the literature deals with comprehension or comprehension criteria levels which can be related to safe driving performance.

The only published comprehension criteria standard is that of the Standards Association of Australia (SAA) (1980). In the Australian Standard for the Design and Use of Graphic Symbols and Public Information Symbol Signs (AS 2342), they set out standardized test procedures and evaluation criteria for traffic signs. These test procedures are not new. They are comprised of an initial preference rating, an open-ended comprehension test, and

an open-ended comprehension test after learning the meanings of the test signs. The key element in the standard is the establishment of "acceptability criteria." One criterion is that at least 85 percent of the subjects must correctly identify the sign being tested in the open-ended comprehension with learning test. It is also stipulated that no more than 5 percent of the sample may give a response which is considered directly opposite in meaning to the correct meaning of the sign, and no more than 10 percent of the sample may give inappropriate responses.

As stated earlier this is the only set of comprehension related criteria for traffic signs that exists today, but even these values are suspect. In a study by Johnson (1980) several new signs were tested using the SAA technique. Weaknesses were found in using this technique because the study results showed that the testing lacked discriminative power, an ability to show differences between sign candidates, and it was made quite clear that the criteria values are not based on any empirical evidence. The initial open-ended comprehension test proved to be a more discriminating measure of the differences between the different signs tested. Even though AS 2342 has been criticized, it is still the only standard unearthed, and it appears that no others exist.

The International Organization for Standardization (ISO) has been working in the area of symbol sign evaluation for many years. A synthesis of these efforts relating to public information symbols has been published, but it is not known if the report has been adopted as an ISO standard (Easterby, 1980). The most important aspect of the report is that a minimum comprehension criteria of 66 percent is used for determining acceptability of symbolic public information signs. The only problem with using the value in this project is that it has yet to be determined if

the criterion is based on empirical evidence, and it is a value for use with public information signs, not traffic control signs.

With such a paucity of information regarding this important aspect of comprehension criteria, other areas of human performance which may be germane to the project were examined. Psychological data bases were searched for any items pertaining to human comprehension performance and its measurement. This search yielded studies dealing with minimum reading competency (Henderson, 1980) and an assessment of fire safety symbols (Collins & Lerner, 1982). While the Collins and Lerner study was very similar to this project, testing the understandability of symbolic warnings, acceptable minimal criteria values were not specified.

The next step in this ancillary search examined the possible relationship between operations research methodologies and establishing human performance criteria. This effort yielded a study of the use of quantitative methods in the assessment of neurological functions (Potvin, Tourtellotte, Syndulko, & Potvin, 1981), unfortunately these methods focused on strict clinical neurological testing procedures. Another reference was an overview of the relationship between human factors and reliability theory (Swain, 1969).

An examination of military standards was completed to see if any performance criteria values could be found. These studies included work in pilot training (Braune & Trollip, 1982) and pilot performance (Cotton, 1978), human factors evaluation procedures used by the U.S. Navy (Malone & Shenk, 1976), and human engineering design criteria standards from the U.S. Department of Defense (1974). Although all of these references sounded promising, none yielded any numerical comprehension criteria.

Finally, a search was made in the area of driver licensing testing to see if there was a way to tie in written driver testing performance scores to a minimally acceptable sign comprehension value. Several promising titles were found (Waller & Vanosdall, 1974; Jones, 1978; McKnight & Edwards, 1982), but no actual criteria values were specified.

Problem Sign Identification from Literature Sources

Besides identifying research methods and information about comprehension, the literature search attempted to indicate which signs have a definite quantifiable comprehension problem. This was evident in many of the studies reviewed. To facilitate the identification of the problem signs, a Problem Sign Identification Form (PSIF) was developed to summarize and incorporate the data derived from the three subtasks. The information regarding comprehension problems cited in the literature is included on the PSIF, which can be found in appendix A.

PROFESSIONAL INPUT

In addition to the literature review, contacts were made with many highway engineering, safety, and driver education professionals to solicit information regarding motorist sign comprehension problems. The sources contacted represented a cross-section of Federal, State, and local government employees; members of professional organizations and advisory groups; university and secondary school educators; and private consultants. A conscious effort was made to contact people in different size states in all regions of the country, as well. In all, 34 contacts were made.

The responses of each source were recorded on a contact log sheet. The information from the contact logs was summarized by sign and entered on the Problem Sign Identification Form in appendix A.

Considering the many definitions of comprehension found in the literature, the concept of comprehension is a rather elusive one. Rather than attempt to explain exactly what comprehension meant in this study, it was decided to ask the experts to identify any sign which they felt had "problems," whether they be "comprehension" problems of conspicuity, legibility, or understanding; or compliance or operational problems. While it was made clear that the primary thrust of the study was to identify signs which are misunderstood, the solicitation of responses about any "problem" sign was made so that the experts would not limit their responses to only those signs they felt had clearly documented evidence of a problem.

The problem cited most frequently was the confusion between the ADVANCE PEDESTRIAN CROSSING sign (W11-2), the PEDESTRIAN CROSSING sign (W11A-2), the SCHOOL ADVANCE sign (S1-1), and the SCHOOL CROSSING sign (S2-1). The contacts felt that the subtle differences in shape between the school and pedestrian signs and the addition of the crosswalk lines on the crossing signs is usually not noticed by the motorist. Although most felt that the concept of "pedestrians crossing the road somewhere" is understood; the age of the pedestrians, times when these crossings would be most active, and the actual crosswalk location were the concepts missed by the drivers.

A similar type of problem that some people noted was the confusion between the RAILROAD ADVANCE WARNING sign (W10-1) and the RAILROAD CROSSING (Crossbuck) sign (R15-1). Again, most motorists are aware of the concept intended, they are approaching an at-grade highway-railroad crossing, but they cannot differentiate between the advance warning and the actual track location warning.

Another pair of signs which was frequently mentioned is the STOP AHEAD symbol sign (W3-1a) and the YIELD AHEAD symbol sign (W3-2a). Several individuals contacted expressed some reticence in using these signs because they felt that the signs might be confused with actual STOP (R1-1) or YIELD (R1-2) signs. No one could relate any experiences where this misinterpretation was made by a motorist, but this opinion did exist. Others explained that they had a problem with motorists interpreting the "ahead" arrow as an indication of the road alignment. The drivers would equate the straight arrow with a straight roadway alignment. This problem of interpreting too "literally" the message of the signs has also been found to apply to the CROSS ROAD sign (W2-1). Many motorists want to interpret the depicted straight approaches as the actual alignment of the road.

Some experts stated that many of the signs which give information about alignment are not fully understood by drivers. It was felt that these signs are interpreted as exact depictions of the roadway alignment rather than representations of the road. The REVERSE TURN/CURVE signs (W1-3, 4) and the WINDING ROAD sign (W1-5) were mentioned as examples of this. It was also noted that there is a lack of consistency in depicting the roadway. For the TURN/CURVE signs (W1-1, 2) the road is represented as a solid black line, but on other signs, such as the LANE REDUCTION TRANSITION sign (W4-2) and the SLIPPERY WHEN WET sign (W8-5), the road is the background color of the sign.

Several contacts felt that there is some confusion about the DIVIDED HIGHWAY and the DIVIDED HIGHWAY ENDS signs (W6-1, 2). Many drivers assign the opposite meanings to these signs, interpreting one as the other and vice versa. Both of these signs are also confused with the KEEP RIGHT sign (R4-7).

Many signs were identified as ones where the sign itself is not understood because the traffic engineering principles behind the reason for its placement are not well understood by the public. A good example of this is the LIMITED SIGHT DISTANCE sign (W14-4). Since this is a word message sign one would expect it to be almost universally understood, but the concepts of sight distance, vertical curves, and horizontal curves are foreign to most drivers; that is why this sign is not correctly interpreted by motorists. Other signs were mentioned which fall into this category. Those noted and their associated conceptual difficulty include: YIELD (R1-2) and MERGE (W4-1) signs, questions about who has the right-of-way; YIELD ON GREEN ● (Maryland R1-2c), complete unfamiliarity with the concepts of protected and permissive signaling phasing; TWO-WAY LEFT TURN ONLY sign (R3-9a), confusion about in which lanes turns are allowed; ADVISORY SPEED PLATE (W13-1) and ADVISORY EXIT/RAMP SPEED signs (W13-23), confusion with the SPEED LIMIT sign (R2-1); SCHOOL BUS STOP AHEAD (S3-1), motorist's failure to realize this sign is used only on "blind" horizontal or vertical curves.

Other signs were mentioned as causing operational/safety problems where the reason might be improper placement, a motorist comprehension problem, or a combination of these. Violators of these signs would often offer as an excuse that "they didn't see the sign." The question of whether or not they "saw" the sign becomes dichotomized into did they not "see" and understand the sign or was the sign placed where they would not be "looking" for it. The NO LEFT/RIGHT TURN signs (R3-1, 2) are an example of this. Some contacts felt they had poor compliance with these signs. Initially, it was thought that the signs were not very well understood. Now, the feeling is that the signs are probably understood, but size and placement play a bigger role in the compliance problem. Other signs where an examination of current

placement practices might solve operational or safety problems were the ONE WAY sign (R6-1) and the NO TURN ON RED sign (R10-11a).

Several signs were cited as having symbols which are misunderstood, and seem to have non-traffic interpretations attached to them by motorists. Signs mentioned which fall into this category are TOURIST INFORMATION (D9-10), described as "the big question mark"; NARROW BRIDGE (W5-2a), known as "the spider"; PAVEMENT ENDS (W8-3a), "the gas pump"; SLIPPERY WHEN WET (W8-5), "beware of drunk driver"; and the WORKER (W21-1) symbol, "man with the broken umbrella."

TORT LIABILITY REVIEW

The tort liability review was an extensive search of all the reported judicial decisions in the United States since 1978 that dealt with highway signing. These cases were examined in detail to determine if sign design or placement in any way contributed to, or was the proximate cause of the resulting motor vehicle accident.

It is important to preface the review with some comments regarding the method in which judicial decisions are recorded and preserved for future study and reference. In almost all jurisdictions, only the opinions of appellate courts are preserved, as these courts are usually the only "courts of record." A court of record is a court in which the proceedings are monitored by a court reporter and reproduced onto transcripts. The judge reviews the transcripts and renders a written opinion or decision, which later appears in a State, regional, or Federal reporter volume. This process has particular significance in attempting to perform a tort liability study involving motor vehicle accidents and

highway signing, since motor vehicle accidents which do not involve great monetary damages or loss of life are not usually the subject of litigation in the appellate courts. More frequently, these cases are heard in traffic courts, or are settled between the parties without reaching the appellate courts. Even when an automobile accident case reaches an appellate court, it is rarely on an issue of fact, such as the placement of a highway sign. Such an issue would usually be resolved in the lower courts, which are generally not courts of record. More likely, the case on appeal would be before the court on a disputed legal issue, such as sovereign immunity or legal fault, with little discussion of the facts as found by the lower court.

The review was performed at the George Mason University School of Law, utilizing its computerized case-finding systems. The bulk of the search was performed on the LEXIS legal research system. LEXIS is a computer system that enables one to search the full text of recent cases from the Federal level and all the courts of record in all 50 states. Through its search logic and data base, cases can be retrieved by matching relevant words and phrases to their occurrences in the primary case data base.

The data base that was chosen for use in this review contains the opinions of all the state court cases decided since the early 1900s and many State Attorneys General reports. The initial search request entered into the system was chosen to extract all automobile accident cases in which a sign was involved. This broad request produced 22,176 cases. The request was then modified by limiting the study to those cases decided after January 1, 1978. This narrowed the cases fitting both requests to 5,112 cases. The next search request was designed to isolate those cases involving questions about sign comprehension, design or placement.

This search request narrowed the 5,112 cases to 1,009 cases. The next search request extracted those cases dealing solely with regulatory, warning, and symbol signs and narrowed the field to 675 cases.

All of the 675 cases extracted by the search requests were examined to determine those cases that best expressed the previously enumerated factors involving placement and motorist comprehension. From the original 675 cases, 129 cases were selected for review.

A detailed examination of the actual opinions in the regional or State reporters was performed in order to further determine the best cases for this study. This process yielded approximately 52 cases which were orally briefed and critiqued. From those cases, 23 cases were chosen for inclusion in this study.

In order to identify those cases involving motor vehicle accidents and highway signing which did not specifically use the word "automobile" in their court opinions, a second set of search terms was then entered into the LEXIS system. This request enabled the system to extract all of the other motor vehicle accident cases involving signing that did not appear in the first group of 675 cases. This request yielded 207 additional cases; however, most of these did not actually deal with the subject matter of the study. Upon review of these 207 decisions, five additional cases were critiqued and have been used in this study.

Finally the search requests were run through the system's Federal library data base. This precaution was taken because some cases might have been "removed" to the Federal court system because of diversity of citizenship (cases involving citizens of two or more states). Even though such cases may be heard in a Federal court, Federal law requires that the claims raised be

adjudicated on the basis of the relevant State law. This search yielded four additional cases, none of which was suitable for this study.

Unfortunately, most of the final 28 cases involved matters of sign placement or failure to erect the proper sign rather than comprehension. This information was summarized and included on the Problem Sign Identification Form in appendix A. Three specific cases contained elements of a comprehension problem. A brief summary of each of those cases follows.

In the case of Kitt vs. Yakima County, Wash., 611 P. 2d 1234 (1980), all four approaches to an intersection were signed by the defendant, Yakima County, with CROSS ROAD signs (W2-1). The plaintiff testified that the placement of a CROSS ROAD sign on the road on which he was traveling was an indication that he was on the major or through road and therefore had the right-of-way. The defendant contended that it was not unusual to sign all four approaches to an intersection in this manner, but under cross-examination, defendant's witnesses could not cite another example of this practice in the county. The State supreme court reversed the decision of the appellate court which had reversed the decision of the trial court which had found for the plaintiff.

In the case of Salvati vs. Department of State Highways, 92 Mich. App. 452, the plaintiff's husband was killed when he lost control of his automobile on an icy bridge. On the approach to the bridge was a sign, WATCH FOR ICE ON BRIDGE. The court's opinion was that the sign WATCH FOR ICE ON BRIDGE cannot be meaningful if "it gives no instruction to motorists as to the action or precaution to be taken if there is ice on the bridge." The trial court found for the plaintiff. On appeal, the decision was affirmed.

In the case of City of Indianapolis vs. Swanson, 448 N.E. 2d 668 (Ind. 1983), the defendant was driving his automobile on an unfamiliar road when he encountered a LEFT REVERSE CURVE sign (W1-4). The physical situation was that the first curve to the left was very slight and the following curve to the right was much more severe. Since the first curve was so slight, the plaintiff drove through the first curve unaware that this was the left curve referred to by the sign. While he approached the sharper curve to the right, he still was expecting to encounter a left curve. He turned his vehicle to the left as the road turned to the right. His car left the road and struck a tree. The State supreme court reversed the original trial court decision, which was in favor of the plaintiff.

CHAPTER 3
PROBLEM SIGN IDENTIFICATION

This chapter covers the selection of the traffic signs which caused the greatest comprehension problems to motorists. The signs identified in this effort were redesigned to see if changes to the entire sign or specific elements of the sign improved levels of comprehension.

Initially, the concept of comprehension was defined within the scope of this study. Criteria for assessing levels of comprehension were structured to allow selection of the signs with the "worst" problems. These criteria were used later to select the best redesigned signs.

Choosing a sign with the lowest comprehension level did not necessarily mean picking the sign which could cause the most dangerous situation on the road. A combination of consequences and types of misunderstandings along with comprehension levels dictated which signs were slated for redesign.

Once the signs were identified it was necessary to identify the problems and causes of problems for each individual sign. Knowledge of the problems and causes allowed for more effective redesign efforts.

CRITERIA FOR MOTORISTS' SIGN COMPREHENSION

Since there are many test techniques used to evaluate traffic signs and many of the journal articles reviewed contain the word "comprehension," it is clear that comprehension means different things to people. In fact, many of the tests measure similar

characteristics of the sign or human performance response to sign stimuli, but they go under different names. These tests include:

- Conspicuity/Detection/Target Value - These techniques test subjects' ability to notice a sign's presence or the ability to pick out signs from a complicated background.
- Day/Night Legibility - These tests measure the subjects' ability to recognize the sign at varying distances from the sign in varying ambient lighting.
- Glance Legibility/Duration of Exposure/Reaction Time/ Meaning Latency - These types of testing gauge the subjects' ability to quickly recognize the sign presented. One form of the test allows the subject a brief period to view the sign and respond. The other measures the time from onset of the stimulus until the subject responds.
- Understandability/Accuracy/Comprehension - These tests simply ask the subjects to tell what the sign means.
- Certainty of Meaning - When subjects reply when asked to tell the meaning of the sign, they are asked to tell how sure they are about their answers.
- Learnability/Ability to Remember - In these tests the subjects are told the meaning of the sign and after an interim time period has elapsed, they are shown the sign and asked what the sign means.
- Action Response - In this type of testing the subjects are asked how their driver behaviors would change if they saw the sign in question.
- Preference - The subjects are shown several candidate signs for one signing purpose and asked which one is preferred.

Many arguments have been advanced as to the validity and importance of each of these techniques. They are all valid to a degree, but their relative importance to the initial design process varies. It can be argued that only two of these measures are of real importance in the initial design process. These would be conspicuity and understandability. Conspicuity is a measure of how well the sign "stands out" from its background or how often it is noticed. Clearly, in order to be able to read and understand a sign one must realize that there is a sign in the first place, or how can a person read a sign he cannot see?

Understandability is a measure of how well the meaning or intent of the sign is communicated. It is good that a motorist can notice a sign along the road, but if he pulls over, stops, and looks at the sign and cannot even guess the message that the sign is trying to convey then the situation is no better than if he did not detect the sign in the first place. It can be argued further that conspicuity can be improved by varying the contrast between the sign legend and sign background or the sign background and visual environment, but meaning and the understanding of a concept are areas where variance of strict physical parameters are not likely to improve performance. Therefore, comprehension as defined in this study is cognitive understanding of a concept represented by a sign.

It has been shown, through a search of the literature, that there is very little in the way of actual comprehension criteria levels. The only published standard is that of the Standards Association of Australia (AS 2342), but even the values established therein have been criticized as being arbitrary with no empirical data to back up these criteria (Johnson, 1980). Comprehension criteria levels should specify how many people know what a sign means before it can be considered safe enough to put on the street.

A performance criteria of 100 percent is unrealistic. Because of the nature of human performance, a performance level of 100 percent is not a frequent occurrence. Even in previous studies none of the traffic control devices tested had understanding levels of 100 percent. In the Bolt, Beranek, and Newman study (Jones, 1972) there seem to be expected levels of error for any sign tested. On the other hand, extremely low levels of performance cannot be tolerated. In the Hulbert and Fowler study (1980), the ADDED LANE sign (W4-3) was understood by only 7 percent of the subjects tested. This means that this sign has negligible safety benefits versus the cost of fabricating and placing a sign which is understood by only a few motorists.

Originally, it was planned to have a decision matrix based on comprehension level and the consequence of a motorist misunderstanding a sign (i.e., its relative importance). This would have allowed the development of a sliding scale criterion which would have been situation dependent, but again there is no information as to what is an appropriate comprehension level for any sign no matter how "important" it is.

Therefore, each sign identified as a problem sign was tested along with the newly generated alternatives in search of what can quite simply be called the "winner." Whichever sign performed the best according to the testing techniques used in the laboratory, simulator, and in the field became the new sign. If none of the signs tested met an established minimum (e.g., the 66% comprehension criteria for travel information signs recently considered by ISO), the winning sign was categorized as "provisional" and slated for further remedial work.

PROBLEM SEVERITY RATING

From the previous discussion, it is apparent that specific comprehension criteria levels related to each sign or the creation of a blanket criterion could not be attained. For that reason the problem sign identification process took a slightly different tack than originally anticipated, but the process of identifying any sign with a potential comprehension problem and prioritizing those signs identified remained the same.

It was decided that any sign included on the Problem Sign Identification Form would be given some consideration as being a possible problem sign. After an initial review of the PSIF, it was found that many signs were identified by only one information source; shown to have a placement problem primarily; or they were word message versions of already identified symbol signs. Because of what was considered weak or irrelevant evidence for their inclusion as actual problem signs, these signs were eliminated from further consideration or "thrown out." Each of the remaining signs was evaluated in terms of three factors which addressed the effects and the depth of the comprehension problem for each sign. The three factors were consequence of miscomprehension, type of miscomprehension, and degree of miscomprehension.

Consequence of miscomprehension considers the worst case of motorist response if the sign is misunderstood, e.g., a motorist misinterpreting a KEEP RIGHT sign could enter a lane of oncoming traffic and be involved in a head-on collision. The consequence severity for each sign was examined and a numerical rating of 1 (trivial) to 3 (severe) was used to rate the consequence problem. Type of miscomprehension assesses the degree to which the sign is misinterpreted, e.g., the ADVANCE SCHOOL CROSSING sign is interpreted as the SCHOOL CROSSING sign. The differing interpretations

of each sign were reviewed and a numerical rating of 1 (close interpretation) to 3 (opposite interpretation/no interpretation) was given to each sign. Degree of miscomprehension uses information from sign comprehension studies to scale the magnitude of the misinterpretation problem, e.g., only 7 percent of the drivers tested could correctly identify the ADDED LANE sign (Hulbert & Fowler, 1980). The amount of miscomprehension for each sign was translated into a numerical value. Incorrect responses from 0 to 10 percent of the subjects tested were given a value of 1. Signs having incorrect responses from 11 to 20 percent of the motorists tested were assigned a value of 2. Incorrect responses by more than 20 percent of the test subjects would earn a sign a value of 3. Many of the signs identified in chapter 2 had not been tested in any sign comprehension studies, these signs were assigned an arbitrary value of 2.

After a rating was assigned to each factor for each sign, the individual ratings were totaled to yield an overall problem severity rating for each sign. The overall problem rating could range from a value of 3 (no real comprehension problem) to 9 (very severe comprehension problem). A form was designed to facilitate the prioritization work. This Problem Severity Rating Form (PSRF) gives the reasoning behind the numerical rating for each factor and the actual rating for each sign considered. The PSRF is included as table 1. The result of this process is a list of problem signs grouped by severity value. This list is shown in table 2. From this list, the signs with a rating of 7, 8, or 9 were chosen as the signs with the most severe comprehension problems and most in need of redesign. It was decided to eliminate from this group of signs certain candidates which were studied extensively in the past, under current analysis, or planned to be examined in future research. On this basis the RAILROAD CROSSING (Crossbuck) sign, R15-1; YIELD ON GREEN ● sign, MR1-2c; RAILROAD ADVANCE sign, W10-1; LIMITED SIGHT DISTANCE sign, W14-4; and

Table 1. Problem severity rating form.

SIGN	MUTCD CODE	CONSEQUENCE OF MISCOMPREHENSION	RATING	TYPE OF MISCOMPREHENSION	RATING	DEGREE OF MISCOMPREHENSION	RATING	OVERALL RATING
YIELD	R1-2	Potential vehicle/vehicle angle sideswipe or rear end conflict	3	The sign itself is read and understood, but the traffic engineering concept of yielding is not fully understood in the many situations in which it applies.	2	Based on the intended meaning of the sign, comprehension is bad, but the cognizance of a YIELD sign is good.	1	6
YIELD ON GREEN ●	N/I	Driver crosses approaching traffic stream assuming that he is in a protected movement.	3	Total lack of understanding	3	N/I	2	8
SPEED LIMIT	R2-1	Vehicle travels too fast or too slow for prevailing conditions.	2	Message is disregarded.	1	N/I	2	5
SPEED ZONE AHEAD	R2-5c	Vehicle travels faster than prevailing conditions allow.	2	Ambiguous message which is not fully understood	2	N/I	2	6
NO LEFT/RIGHT TURN	R3-1 R3-2	Potential for illegal turning movements or wrong way driving	2	Curve or turn ahead	2	In 1972, 39% of the drivers tested recognized these signs. By 1979, the comprehension level had improved to 92%.	1	5
NO U TURN	R3-4	Traffic flow impedence	1	Curve warning sign	2	In 1972, 66% of the drivers tested recognized this sign. By 1979, the comprehension level had improved to 97%.	1	4
LANE USE CONTROL	R3-5	Potential vehicle/vehicle angle, sideswipe or rear end conflicts at relatively low speeds.	1	Motorists sometimes believe that turns are allowed from adjacent lanes as well.	2	N/I	2	5
LANE USE CONTROL	R3-8	See R3-5.	1	Some motorists believe that turning from the right lane is not allowed.	1	Ninety-five percent of the drivers tested had a non-disasterous interpretation of this, while 66% understood it fully.	2	4
TWO WAY LEFT TURN	R3-9a	Potential vehicle/vehicle head on or rear end conflict; Traffic flow problems from left turning vehicles in the through lanes.	3	Use the turn lane as a travel lane	3	N/I	2	8

Table 1. Problem severity rating form (continued).

SIGN	MUTCD CODE	CONSEQUENCE OF MISCOMPREHENSION	RATING	TYPE OF MISCOMPREHENSION	RATING	DEGREE OF MISCOMPREHENSION	RATING	OVERALL RATING
DO NOT PASS	R4-1	Vehicle attempts to pass in an area where the sight distances are inadequate to do so.	3	Apparent placement problem	1	N/I	2	6
PASS WITH CARE	R4-2	Motorists won't pass when they are allowed to do so.	1	Ambiguous message which is not fully understood	2	N/I	2	5
KEEP RIGHT	R4-7	Motorist could move into an oncoming traffic lane.	3	Sign has been interpreted as "lane ends," or "traffic island ahead."	2	In 1972, 76% of the drivers tested identified the proper driving maneuver; 74% recognized this sign. By 1980 the comprehension level remained at 74%.	3	8
DO NOT ENTER	R5-1	Potential vehicle/vehicle head on conflict	3	Emergency facility	3	Comprehension is extremely poor without words, not tested otherwise.	2	8
TRUCK EXCLUSION	R5-2	A truck is on a road that it should not be.	2	Watch out for trucks	2	In 1972, 54% of the drivers tested identified this sign correctly, but "circle-slash" prohibition has shown improved levels of comprehension.	1	5
BICYCLE EXCLUSION	R5-6	A bicycle is on a facility that it should not be.	2	Watch out for children	2	In 1972, 30% of the drivers tested identified this sign correctly, but "circle-slash" prohibition has shown improved levels of comprehension.	1	5
RAILROAD CROSSING (CROSSBUCK)	R15-1	Potential vehicle/train angle conflict	3	Railroad advance warning	2	In 1981, 71% of the drivers tested correctly identified this sign.	3	8
TURN	W1-1	Potential for a vehicle to leave the roadway or encroach into an oncoming lane. In wet pavement conditions, vehicles are more susceptible to skidding.	3	This sign is often confused with the CURVE sign which could cause motorists to underestimate the severity of the turn. It is viewed as an actual view of geometric conditions rather than a representation.	2	In 1978, 20% could not differentiate between the TURN and CURVE sign.	2	7
CURVE	W1-2	See W1-1.	3	See W1-1.	2	In 1972, 57% of the drivers tested correctly identified this sign.	3	8

Table 1. Problem severity rating form (continued).

SIGN	MUTCD CODE	CONSEQUENCE OF MISCOMPREHENSION	RATING	TYPE OF MISCOMPREHENSION	RATING	DEGREE OF MISCOMPREHENSION	RATING	OVERALL RATING
REVERSE TURN	W1-3	See W1-1.	3	This sign is interpreted as an exact diagram of the physical geometric conditions.	2	N/I	2	7
REVERSE CURVE	W1-4	See W1-1.	3	See W1-3.	2	N/I	2	7
WINDING ROAD	W1-5	See W1-1.	3	See W1-3.	2	In 1972, 68% of the drivers tested correctly identified the intent of this sign.	3	8
CROSS ROAD	W2-1	Potential vehicle/vehicle angle or rear end conflict	3	Some motorists are confused as to which legs of the intersection constitute the main or through road.	2	In 1972, 72% of the drivers tested correctly identified the intent of this sign.	3	8
STOP AHEAD	W3-1a	Potential vehicle/vehicle angle or rear end conflict	3	The "ahead" arrow on this sign is interpreted by many motorists to be an indication of the road alignment	2	In 1980, 84% of the drivers tested chose the correct definition, but in a different test situation one year later only 40% could give a correct definition for this sign.	3	8
YIELD AHEAD	W3-2a	See W3-1a.	3	See W3-1a.	2	In 1980, 86% of the drivers tested chose the correct definition for this sign.	2	7
MERGE	W4-1	Potential vehicle/vehicle sideswipe or rear end conflict at relatively high speeds	3	Motorists are often confused about who has the right-of-way.	3	In 1978, 80% of the drivers tested correctly defined this sign.	2	8
LANE REDUCTION TRANSITION	W4-2	Potential vehicle/vehicle sideswipe conflict; Single vehicle could move off paved surface.	3	One lane traffic ahead	2	In 1978, 61% of the drivers tested correctly defined this sign. By 1979, the comprehension level had improved to 87%.	2	7
ADDED LANE	W4-3	Potential vehicle/vehicle rear end conflict; Vehicle slowing; Decreased ramp capacity.	2	Interpreted as MERGE (W4-1) sign	2	In 1980, only 71% of the drivers tested could identify this sign.	3	7
NARROW BRIDGE	W5-2a	Vehicle may strike bridge rail or encroach into the oncoming traffic lane.	3	Total lack of understanding	3	In 1984, 84 to 93 percent of the subjects tested chose an "essentially correct" definition for this sign.	2	8

Table 1. Problem severity rating form (continued).

SIGN	MUTCD CODE	CONSEQUENCE OF MISCOMPREHENSION	RATING	TYPE OF MISCOMPREHENSION	RATING	DEGREE OF MISCOMPREHENSION	RATING	OVERALL RATING
ONE LANE BRIDGE	W5-3	Potential vehicle/vehicle head on conflict; Vehicle may strike bridge rail.	3	None known	1	N/I	2	6
DIVIDED HIGHWAY	W6-1	Potential vehicle/object conflicts	2	Confused with KEEP RIGHT (R4-7)	1	In 1978, 98% of the drivers tested had a firm concept of keeping to the right of "something."	1	4
END DIVIDED HIGHWAY	W6-2	Possible encroachment into an opposing traffic lane; Potential vehicle/vehicle head on conflict.	3	Interpreted as DIVIDED HIGHWAY (W6-1)	3	In 1972, 55% of the drivers tested correctly defined this sign.	3	9
HILL SIGN	W7-1	Potential vehicle "runaway" problem; Speed too great for conditions.	2	Thought of as only applying to trucks	2	In 1972, 67% of the drivers tested correctly defined this sign.	3	7
PAVEMENT ENDS	W8-3	Speed too great for roadway conditions	2	Interpreted as "Highway ends, prepare to exit"	1	In 1978, 98% of the drivers tested had the intent of the meaning.	1	4
PAVEMENT ENDS (SYMBOL)	W8-3a	Speed too great for roadway conditions	2	Interpreted as a "gas pump"	3	N/I	2	7
SOFT SHOULDER	W8-4	Potential for a vehicle to catch a tree or roll over	3	None known	1	In 1978, 88% of the subjects tested correctly defined the SOFT SHOULDER sign.	2	6
LOW SHOULDER UNEVEN PAVEMENT	W8-4B W8-4C	Potential steering, control or roll over problems	3	Numerous wrong interpretations	2	A survey done in 1984 shows that there is little public knowledge of these signs.	3	8
SLIPPERY WHEN WET	W8-5	Vehicle speed too great for wet weather conditions; Potential skidding hazard.	2	Interpreted as "winding road ahead" or "drunk drivers ahead"	3	In 1978, 75% of the drivers tested correctly identified this sign.	3	8
ADVANCE RAILROAD CROSSING	W10-1	Potential vehicle/train angle conflict; Potential vehicle/vehicle rear end conflict.	3	Interpreted as the actual locator of the tracks	2	In 1972, 76% of the drivers tested correctly identified this sign. In 1980, 92% chose an answer identifying this sign as a warning of railroad crossing but did not differentiate it as an advance warning. In 1981, only 62% identified this sign as advance signing.	3	8

Table 1. Problem severity rating form (continued).

SIGN	MUTCD CODE	CONSEQUENCE OF MISCOMPREHENSION	RATING	TYPE OF MISCOMPREHENSION	RATING	DEGREE OF MISCOMPREHENSION	RATING	OVERALL RATING
PEDESTRIAN CROSSING SIGNS	W11a-2 W11-2	Potential vehicle/pedestrian conflict	3	Often confused with the school crossing signing	1	In 1972, 48% of the drivers tested correctly identified this sign.	3	7
LOW CLEARANCE	W12-2	Oversize vehicle strikes low-hanging object.	2	Not understood	3	In 1972, 68% of the drivers tested correctly identified this sign.	2	7
NO PASSING PENNANT	W14-3	Passing in an area where it is unsafe to do so	3	Primarily a placement problem	1	N/I	2	6
LIMITED SIGHT DISTANCE	W14-4	Potential for striking an object in the road, encroaching into oncoming traffic lanes or leaving the roadway	3	The concept of sight distance is totally foreign to drivers.	3	N/I	2	8
ONE LANE ROAD	W20-4	Potential vehicle/vehicle head on conflict	3	Ambiguous in that there is no communication that the one lane has to handle traffic in both directions	2	N/I	2	7
XXX LANE CLOSED	W20-5	Vehicle may encroach into work area; Late lane change could be potentially hazardous or an impediment to flow conditions.	2	Confusion between the stimulus, "right/left lane closed" and the implied command "merge left/right"	2	N/I	2	6
ADVANCE FLAGGER	W20-7a	Potential vehicle/flagger conflict; Encroachment into work area; Potential vehicle/vehicle head on or rear end conflict.	3	Total lack of understanding	2	In 1981, 83% of the drivers tested correctly identified this sign.	2	8
WORKERS	W21-1a	Potential encroachment into a utility/minor maintenance area.	3	Total lack of understanding	3	N/I	2	8
ROAD MACHINERY AHEAD	W21-3	Potential vehicle/vehicle conflict	2	Additional information regarding location is necessary. (Are there machines operating on the road or shoulder areas?)	2	N/I	2	6

Table 1. Problem severity rating form (continued).

SIGN	MUTCD CODE	CONSEQUENCE OF MISCOMPREHENSION	RATING	TYPE OF MISCOMPREHENSION	RATING	DEGREE OF MISCOMPREHENSION	RATING	OVERALL RATING
SCHOOL ADVANCE	S1-1	Potential vehicle/pedestrian conflict; Inappropriate speed for school area.	3	Confused with the SCHOOL CROSSING (S2-1) and pedestrian signs (W11-2, W11A-2)	2	In 1978, 33% of the drivers tested could not differentiate between S1-1 and S2-1. Fifteen percent identified S1-1 as W11A-2. In 1979, only 18% identified S1-1 correctly. In 1984, 21% identified S1-1 correctly. Forty-two percent identified S1-1 as S2-1. Thirty-one percent identified S1-1 as W11A-2.	3	8
SCHOOL CROSSING	S2-1	See S1-1.	3	See S1-1.	2	In 1979, 45% of the drivers tested identified S2-1 correctly.	3	8
SCHOOL BUS STOP AHEAD	S3-1	Potential vehicle/pedestrian conflict; Potential vehicle/vehicle rear end conflict.	3	Motorists fail to tie in sign message with a limited sight distance problem. Temporal applicability of the sign causes disregard.	3	N/I	2	8

Table 2. Sign comprehension-problem severity.

9's	
W6-2	End Divided Highway Sign
8's	
MR1-2c	Yield on Green O Sign
R3-9a	Two Way Left Turn Only Sign
R4-7	Keep Right Symbol Sign
R5-1	Do Not Enter Sign
R15-1	Railroad Crossing (Crossbuck) Sign
W1-2	Curve Sign
W1-5	Winding Road Sign
W2-1	Cross Road Sign
W3-1a	Stop Ahead Sign
W4-1	Merge Sign
W5-2a	Narrow Bridge Symbol Sign
W8-4a	Low Shoulder Sign
W8-4b	Uneven Pavement Sign
W8-5	Slippery When Wet Sign
W10-1	Railroad Advance Warning Sign
W14-4	Limited Sight Distance Sign
W20-7a	Advance Flagger Symbol Sign
W21-1a	Worker Symbol Sign
S1-1	School Advance Sign
S2-1	School Crossing Sign
S3-1	School Bus Stop Ahead Sign
7's	
W1-1	Turn Sign
W1-3	Reverse Turn Sign
W1-4	Reverse Curve Sign
W3-2a	Yield Ahead Sign
W4-2	Lane Reduction Transition Sign

Table 2. Sign comprehension-problem severity (continued).

7's (Continued)	
W4-3	Added Lane Sign
W7-1	Hill Sign
W8-3a	Pavement Ends Symbol Sign
W8-4	Soft Shoulder Sign
W11-2	Advance Pedestrian Crossing Sign
W11A-2	Pedestrian Crossing Sign
W12-2	Low Clearance Sign
W20-4	Advance One Lane Road Sign
6's	
R1-2	Yield Sign
R2-5c	Speed Zone Ahead Sign
R4-1	Do Not Pass Sign
W5-3	One Lane Bridge Sign
W14-3	No Passing Pennant Sign
W20-5	Right/Left Lane Closed (Advance) Sign
W21-3	Road Machinery Ahead Sign
5's	
R2-1	Speed Limit Sign
R3-1,2	Turn Prohibition Signs
R3-5	Lane Use Control Sign
R4-2	Pass With Care Sign
R5-2	Truck Exclusion Sign
R5-6	Bicycle Exclusion Sign
4's	
R3-4	No U Turn Sign
R3-8	Lane Use Control Sign
W6-1	Divided Highway Sign
W8-3	Pavement Ends Sign

Table 2. Sign comprehension-problem severity (continued).

	Thrown Out
R1-1	Stop Sign
R1-3	4-Way Plate
R1-4	All Way Plate
R3-14	Preferential Lane Sign
R4-8	Keep Left Sign
R6-1	One Way Sign
R7-2a	No Parking Sign
R10-11a	No Turn on Red Sign
W1-7	Large Arrow Sign
W1-8	Chevron Alignment Sign
W2-4	T Symbol Sign
W3-3	Signal Ahead Sign
W6-3	Two Way Traffic Sign
W9-1	Lane Reduction Transition Sign
W9-2	Lane Reduction Transition Sign
W11-3	Advance Deer Crossing Sign
W11-4	Advance Cattle Crossing Sign
W12-1	Double Arrow Sign
W13-1	Advisory Speed Plate
W13-2	Advisory Exit Speed Sign
W13-3	Advisory Exit Speed Sign
W14-1	Dead End Sign
W14-2	No Outlet Sign
W20-2	Advance Detour Sign

DO NOT ENTER sign, R5-1, were eliminated from further consideration. The remaining group of 30 signs became the final choice for redesign.

INDIVIDUAL SIGN PROBLEMS

While identifying the signs with comprehension problems, certain "clues" as to why the signs may have a problem surfaced. Very often a sign is not completely misunderstood. Only single elements of the total message are missed. Sometimes the exact opposite interpretation of a sign's message is the meaning taken by the motorist. In some instances the sign's intent is so badly communicated that the motorist cannot offer any kind of interpretation. Following is a discussion of the problems associated with each sign. It is clear that many "families" of signs suffer the same conceptual difficulties. Also, many signs have problems that are situation dependent. Recognition of these facts simplified the redesign process.

W6-2 Divided Highway Ends Sign. This sign is often confused with its "opposite" W6-1, Divided Highway Begins Sign. This may be attributable to the fact that they are the exact same sign rotated 180° for each use.

R3-9a Two-Way Left Turn Only Sign. This sign is one where the problem lies not only with the sign, but also with public familiarity of the traffic engineering concept of two-way left turn lanes. The sign and associated pavement markings should work together to form the total concept.

R4-7 Keep Right Symbol Sign. The curve of the arrow leads some motorists to believe that the alignment of the road is curved or winding ahead.

W1-2 Curve Sign. This sign along with W1-1, Turn Sign, are a pair of signs which cause problems for many motorists because they look so similar. Along with W1-3, Reverse Turn Sign; W1-4, Reverse Curve Sign; and W1-5, Winding Road Sign, they all create similar comprehension difficulties for the motorist. Many motorists interpret these signs as actual diagrams of the roadway alignment ahead, while they are intended as representations only. This is especially true of the reverse turn and curve sign. The degree of curvature and distance between sequential curves is not communicated to the motorist. For example, the first curve may need a curve sign; the second a turn sign. Since they are close together, the reverse turn sign is used. A motorist slows his speed expecting two turns. He passes through the first curve at a speed he feels is too slow. He expects the next turn to be as gentle. He speeds up and enters the turn at an inappropriately high speed. Changing tangent distances between curves can cause problems as well.

W1-5 Winding Road Sign. See W1-2, Curve Sign.

W2-1 Cross Road Sign. Many drivers have a problem transferring this aerial or plan view to their point of view on the roadway. At times, it has been confused with the International Red Cross symbol leading some people to believe it has something to do with hospitals.

W3-1a Stop Ahead Sign. The arrow on this sign sometimes misleads motorists about the alignment of the roadway ahead. Concern was expressed by some experts that the symbol could be interpreted as an actual Stop Sign.

W4-1 Merge Sign. This sign causes some confusion as to which road is the major roadway. It is also confused with W4-3, Added Lane Sign.

W5-2a Narrow Bridge Sign. This use of the plan view of the road and the engineering symbol for a bridge does not allow any interpretation to be made by motorists for this sign.

W8-4a Low Shoulder Sign. This sign, similar to W8-4C, Uneven Pavement, fails to communicate to the driver the true nature of the hazard, steering/tracking problems. If the difference in pavement or shoulder height are extreme, some larger vehicles might be easily overturned.

W8-4b Uneven Pavement Sign. See W8-4a, Low Shoulder Sign.

W8-5 Slippery When Wet Sign. The concept of road being wet/slippery is completely lost. Motorists interpret this sign as "sharp curve" or "drunk drivers ahead."

W20-7a Advance Flagger Symbol Sign. This sign is usually recognized as being part of a construction or work zone, but many drivers fail to realize that they will be receiving traffic control directions from a flagger further down the road. Part of the problem may be an unfamiliarity with the flagging concept of controlling traffic over a one-lane section of road.

W21-1a Worker Symbol Sign. The pictograph for this sign is probably the least understood by motorists. Interpretations have been "man with a broken umbrella," "man feeding a whale," and others.

S1-1 School Advance Sign. This sign is intended to warn motorists that they are approaching a crosswalk used by school children. It is usually followed by S2-1, School Crossing Sign, which shows the actual location of the crosswalk. Most drivers understand the concept of pedestrians crossing the road, but

fail to understand where the crossing actually is or that the pedestrians are school children. The addition of the crosswalk lines on the S2-1 sign seems to be too subtle for most drivers to catch. There is also a great amount of confusion between the S1-1 and S2-1 signs, and the W11-2, Pedestrian Advance Sign, and W11A-2, Pedestrian Crossing Sign. The addition of the school-books in the hands of the children on the S1-1 and S2-1 signs or the difference between the pentagon shape for the school sign and the diamond shape for the pedestrian sign may also be too subtle for most people to notice.

S2-1 School Crossing Sign. See S1-1, School Advance Sign.

S3-1 School Bus Stop Ahead Sign. This sign is to be used in situations where a school bus stop is in an area where there are sight distance limitations. The word message is clearly understood, but the engineering concepts of sight distance and safe stopping distance are not. Some type of active command or supplementary plate (speed or distance) might help the problem. The temporal nature of the sign's applicability causes problems as well (i.e., Are school buses stopping ahead in June, July, and August?).

W1-1 Turn Sign. See W1-2, Curve Sign.

W1-3 Reverse Turn Sign. See W1-2, Curve Sign.

W1-4 Reverse Curve Sign. See W1-2, Curve Sign.

W3-2a Yield Ahead Sign. The arrow on this sign sometimes misleads motorists about the alignment of the roadway ahead. Concern was expressed by some experts that the symbol could be interpreted as an actual Yield Sign.

W4-2 Pavement Width Transition Sign. Difficult for motorists to differentiate between an actual lane drop and a narrowing of the pavement. Some motorists have difficulty differentiating between this sign and its "mirrored" opposite which signifies a left lane ending or closure.

W4-3 Added Lane Sign. See W4-1, Merge Sign.

W7-1 Hill Sign. The truck symbol leads many motorists to think that the warning applies only to trucks.

W8-3a Pavement Ends Symbol Sign. The symbol on this sign seems to be a bit vague to the driver. It has been interpreted as a gas pump.

W8-4 Soft Shoulder Sign. This sign does not have a completely understandable message. If the shoulders are soft, the motorist may ask, "How soft?"; "Do I need to stay off the shoulder?" Some positive command may help here. Some motorists do not understand what the shoulder area is.

W11-2 Advance Pedestrian Crossing Sign. See S1-1, School Advance Sign.

W11A-2 Pedestrian Crossing Sign. See S1-1, School Advance Sign.

W12-2 Low Clearance Sign. Some motorists cannot attach any word meaning to this sign.

W20-4 Advance One Lane Road Sign. The concept that one lane is being used for two-way traffic is not completely clear.

CHAPTER 4
PROBLEM SIGN REDESIGN

Once the final group of problem signs was identified, work began on generating redesigned signs. The designs addressed the specific problems associated with each sign, whether it be aiding the motorist in establishing directional reference, as with the DIVIDED HIGHWAY sign (W6-2), or firmly establishing a concept which may be totally foreign to the driver, such as flagging as a traffic control (ADVANCE FLAGGER sign, W20-7a).

Keeping these types of specific problems in mind, the staffs at BTI and its subcontractor, the Texas Transportation Institute (TTI) at Texas A&M University, generated new candidates for each problem sign. There were no real constraints placed on this effort. Any idea which conveyed the meaning of a sign was considered acceptable in this first phase. This initial step generated a whole host of new signs. The new designs for each sign are shown in Appendix B.

After this first group of sign remedies was completed, several "brainstorming" sessions took place to see how well the new signs addressed the problems associated with the old signs. It had become apparent in the problem identification phase that there are related problems among certain families of signs. In developing the new signs, the initial strategy was to have each design team come up with solutions for each sign individually. In each of the small discussion sessions, it became evident that there were certain common threads running through the solutions as well. This meant that certain design principles could be applicable to many of the problem signs. This subject became a major issue in the redesign process.

The next step in the process was a final discussion among the principal designers from BTI and TTI regarding the new sign ideas and the common design concepts represented. The discussion session was structured so that the first part was devoted to general design principles and concepts. The last part was devoted to a discussion of specific signs. These discussions were used to generate a revised set of candidates that were the basis for the laboratory and simulator testing.

DESIGN PRINCIPLES

The discussion of design principles centered around the lack of uniformity in current signing and the need to address this consideration when developing potential candidates. For example, some existing signs indicate the roadway by using solid lines (i.e., cross road) while others use arrows (i.e., curve and turn signs). Some concern was expressed that this may be a source of confusion to drivers. The following specific design principles were discussed.

Shape Coding

It was felt that the use of unique shapes should be reserved for specific situations. The designers felt that the school-house shaped sign was generally understood. In developing sign candidates that have the symbology running up to the edge, some of the shape coding may be lost. The use of a narrow, high-intensity border may alleviate some of this concern.

Color Coding

It was felt that the driving public generally understood the white/yellow distinction between regulatory/warning signs. Also, it was believed that drivers recognize orange as indicating a

construction zone situation. There was some concern about the target value of some of the candidates. It was felt that some had a black/yellow ratio that was too high.

Symbol Consistency

The Federal position that most signs should be symbols was shared; however, it was felt that this policy is appropriate only if it can be shown that the symbols communicate the appropriate messages. Consistency within sign systems was considered to be especially important. It was felt that drivers who do not read English well may also be the ones who perform poorly on the symbol signing. The symbol sign should be able to stand by itself. If the symbol does not achieve an acceptable level of performance, then serious consideration should be given to verbal messages or a supplemental placard (a discussion of that position follows).

Graphic Orientation

In discussing the advantages and disadvantages of the perspective versus the plan view orientation, it was thought that consistency was more important than absolute performance. It was thought to be better not to have some signs using plan views and others using perspective views. For example, if several of the perspective orientations showed a slightly better (5-10%) level of comprehension in the lab, it was felt that such a small difference would not be sufficient cause to mix perspective and plan view orientations in the recommended signing. There was some discussion that different signing situations warranted different graphic vantage points.

Diagrammatic vs. Symbolic

When developing candidates, it was decided to error on the side of the generic versus the specific representation. For

example, the narrow bridge sign should not have dashed lane markings since passing would typically be prohibited on narrow bridges. Similarly, if drivers do not distinguish between the "turn" and the "curve" arrows then a single degree of curvature indication may be adequate.

Some concern was expressed that drivers may interpret the "ahead" arrow to mean "straight ahead." Since the signs do not always mean "straight ahead," tort liability concerns were raised. The issue of tort liability was frequently mentioned as much as traffic engineers have to be concerned about tort liability in everything they do.

Sign Layout

There was some speculation as to whether or not pictorial and perspective roadway views on signs are read from bottom to top as intended. Also, can drivers relate aerial views to the particular driving situation intended? On signs with arrows (particularly two arrows), it was questioned whether drivers actually associate their position on the road with the proper arrow.

Arrows

With respect to arrows on signs, several questions were raised:

1) Is the shape of the arrow and arrowhead appropriate?
2) Should arrows be used to depict the roadway geometry, vehicle paths, direction of travel, location of hazard, or all these?
3) Should arrows representing different traffic streams be different in color, shape, etc.?

4) There appears to be some inconsistency regarding the use of the word "AHEAD" and the "ahead arrow." Some warning signs (e.g., curve sign) are placed in advance of the hazard with no indication that the hazard is farther down the road, while other signs include the "ahead" indication as part of the message.

Sign Systems

Some traffic signs are used in conjunction with other signs and/or pavement markings to accomplish a traffic control objective. In these applications, a sign's message may be interpreted differently than if the sign was viewed as a solitary traffic control device. Thus, it is important to identify and consider what other traffic control devices will be present when a particular sign is posted. This concern should also be reflected in the testing of the comprehension of the various candidates. The situation or context of the sign/signal system provides important cues to subjects. Testing should provide as realistic a situational context as possible. Similarly, it was felt that driver performance is more important than driver understanding.

Supplemental Panels

It was thought that supplementary placards are appropriate if symbol signs do not achieve a certain threshold of driver understanding and word messages are not considered to be acceptable. Generally, it was felt that supplementary panels should be used when needed for education or increased clarity. Supplemental panels could be placed on a certain percentage (i.e., 10%) of the symbol signs in a system to provide an educational function.

SIGN SPECIFIC DESIGN CONSIDERATIONS

The panel next discussed each of the problem signs and the proposed candidates. The discussion was structured in terms of the following "sign families."

	Family	Sign Number(s)
1.	Curves/Turns	W1-2, W1-5, W1-3, W1-1, W1-4
2.	Pedestrians/School	S1-1, S2-1, S3-1, W11-2, W11A-2
3.	Pavement Cross-Section	W8-3a, W8-4, W8-4a, W8-4b
4.	Pavement Transition	W5-2a, W20-4, W4-2
5.	"Ahead"	W3-1a, W3-2a, W12-2
6.	"Keep Right"	W6-2, R3-9a, R4-7
7.	Merge	W4-1, W4-3
8.	Roadwork	W20-7a, W21-1a
9.	Intersection	W2-1
10.	Grade	W7-1
11.	Slippery	W8-5

Curve Sign (W1-2)

1. Some discussants felt that every curve sign should have an appropriate advisory speed plaque.

Winding Road Sign (W1-5)

1. This sign does not necessarily eliminate the need for curve signing at individual curves.
2. The direction of the first curve (left or right) should be correctly indicated on the sign.

Reverse Turn Sign (W1-3)

1. Some panel members felt that the Reverse Turn sign should be omitted and replaced with a standard Turn sign at each curve.

Reverse Turn Sign (W1-3) (continued)

2. Some panel members felt that an advisory speed plaque (or plaques) should accompany all Turn and Curve signs.

Turn Sign (W1-1)

1. Some of the motorist confusion over this sign may be due to misapplications of the sign (e.g., the Turn sign has been used on curves).

2. The Turn sign should always be accompanied by an advisory speed plaque according to some panel members.

Reverse Curve Sign (W1-4)

1. See comments for Signs W1-5 and W1-3.

School Advance Sign (S1-1)

1. The existing sign does not convey that children will be crossing (i.e., the human images appear to be adults or teens). Opinion favored making the figure heads larger, adding a cap and pigtails, shortening the skirt, and even adding a dog. All these things were felt to be associated with younger children.

2. It was suggested that both a School Crossing and School Advance sign are not necessary. An alternative would be to develop a single "School" sign. When the sign was used in advance of a school or crossing, it would be accompanied with the supplementary plaque "AHEAD." When the sign was used at a crossing, it would be accompanied with the supplementary plaque "X-ING."

3. It was agreed that the unique shape of the school related signs should be retained.

School Crossing Sign (S2-1)

1. As with the School Advance sign, it was thought that the human figures did not look like children. Also, the crosswalk line was not obvious.
2. Racial and gender aspects of the human figures (e.g., pigtails on girl, male larger than female, etc.) were discussed. It was agreed that traffic safety should dictate the sign message.

School Bus Stop Ahead (S3-1)

1. It was felt that this sign was not needed at all. In the words of one discussant, "You can't solve a design deficiency with a sign." Others said, "Move the bus stop."
2. Use of flashing lights in conjunction with the sign was discussed, but it was agreed that such active warnings would be cost-effective only in very rare instances.
3. The word AHEAD could be omitted from the sign face and replaced with a specific distance plaque.
4. The sign could be hinged so that the sign message could be concealed during summer and holiday periods.

Advance Pedestrian Crossing Sign (W11-2)

1. Pedestrians should look like teens or adults.
2. The current human figure looks too much like a jogger.
3. The existing sign does not denote that pedestrians may be in or near the road over a section of roadway.

Pedestrian Crossing Sign (W11A-2)

1. See Sign W11-2 comments.
2. The crosswalk lines are not obvious.
3. There may not be a need for a separate advance and crossing sign.

Pavement Ends Symbol Sign (W8-3a)

1. A simple word message may be the most appropriate message (e.g., GRAVEL ROAD or UNPAVED ROAD).

Soft Shoulder Sign (W8-4)

1. It was agreed that symbolic or pictorial representation of the soft shoulder concept would be very difficult. It may be preferable to have some type of regulatory sign telling drivers to stay off the shoulder.
2. If the sign were hinged, the message could be displayed only when the shoulders were soft.

Low Shoulder Sign (8-4a)

1. A modification of the Uneven Pavement sign may remedy some of the confusion with this existing sign.
2. If vehicles are not to drive on the shoulder, they should not be shown driving on it on the sign face.

Uneven Pavement Sign (W8-4b)

1. See Sign W8-4a comments.
2. There may be no need to show people in the vehicles. However, if people are shown, two people should be in each vehicle.

Narrow Bridge Sign (W5-2a)

1. It was agreed that the narrow bridge message was probably the most difficult to illustrate symbolically or pictorially.

Advance One Lane Road Sign (W20-4)

1. This sign is always part of a signing sequence, thus its interpretation is related to other signs.
2. Cross-hatching connotes temporary lane closure.

Pavement Width Transition Sign (W4-2)

1. The lines may be too thick, obscuring the edge of pavement displacement.
2. The use of the bold lines as the pavement boundaries conflicts with the use of lines on other signs.

Stop Ahead Sign (W3-1a)

1. Removal of the red octagonal shape from the sign face was favored. It could be replaced with a reverse image black-on-yellow shape.
2. There were several comments that the word message "STOP AHEAD" was adequate.

Yield Ahead Sign (W3-2a)

1. As with the Stop Ahead sign, it was questioned whether the red and white Yield sign should be on the face of a warning sign. It could be replaced with a black-on-yellow reverse image Yield sign.
2. The arrow at the top of the sign caused some concern. It seems to conflict with the arrows used on other warning signs.

Low Clearance Sign (W12-2)

1. The use of the arrows is inconsistent with other signs.
2. Some drivers may not understand the abbreviations for feet and inches. However, the sign audience should. Thus, in evaluating sign candidates, the potential sign audience should be considered.

Divided Highway Sign (W6-2)

1. On the existing sign, the graphic representation of the median does not look like a median, and the arrows indicate that drivers must negotiate a reverse curve.
2. Concern was expressed whether the sign is read from bottom to top as intended.

Two-Way Left Turn Only Sign (R3-9a)

1. Some of the candidates are more appropriate for right side mounting and others are better suited for overhead mounting.
2. There is a need to determine if this sign is even needed since it only supplements an extensive pavement marking system.

Keep Right Symbol Sign (R4-7)

1. The curvature of the arrow should be decreased.
2. Drivers may not associate the arrow symbol with their positions on the roadway.

Merge Sign (W4-1)

1. In the aerial views, there was concern over how many travel lanes should be depicted.

Merge Sign (W4-1) (continued)

2. The main debate focused on the issue of whether the arrow symbology was appropriate.

Added Lane Sign (W4-3)

1. It was felt by some that this sign should not be used at all.
2. Some drivers may have difficulty determining which arrow they are represented by.
3. In perspective views, the number of lanes depicted is critical. It may be difficult, however, to develop a perspective view sign which would apply to all situations.

Advance Flagger Symbol Sign (W20-7a)

1. It was agreed that the flagger symbol should be given apparent motion to connote that the flagger is actively controlling traffic ahead.
2. It was felt that the addition of a vest and hard-hat would reinforce that the flagger was an official, important part of the construction or maintenance effort.
3. The addition of a supplementary plaque with the instruction "OBEY" might encourage motorist observance of flagger signals.

Worker Symbol Sign (W21-1a)

1. The existing word message sign (MEN WORKING) was favored over any symbol sign by the TTI designers.
2. It was suggested that the symbol on the sign be given apparent motion to connote that the work is on going.

Cross Road Sign (W2-1)

1. This is one of the signs which is inconsistent with the group of "arrow" signs (i.e., this sign has no arrowheads indicating travel direction).
2. It was suggested that the name of the cross-street could be displayed on a supplementary plaque. This would not only clarify the sign meaning but would give motorists useful advance route information.

Hill Sign (W7-1)

1. It was commented that both length and grade dictate the effective steepness of a hill. Thus, displaying the percent grade may be misleading.
2. There was an attempt to develop a "generic" vehicle which looked like all vehicle types.
3. Motion lines may help bring the sign to life.

Slippery When Wet Sign (W8-5)

1. There is nothing on the sign associated with rain or wet pavement. The addition of puddles and/or raindrops may help (possibly in blue).
2. Showing the vehicle in relief may emphasize that the vehicle is sliding laterally.

Based on the results of this session, a final group of sign candidates was developed. These signs were sent to the FHWA Office of Traffic Operations for their input regarding the traffic engineering implications of the candidates. Their opinion was solicited as to whether any of the candidates should not be tested because they could cause liability problems, contradict another type of traffic control, or cause some other problem which could create a safety or legal hazard. The final group of candidate signs is shown in appendix C.

CHAPTER 5
RESEARCH DESIGN, METHODOLOGY, AND EXPERIMENTAL RESULTS

This chapter describes the laboratory, simulator,* and field procedures used to test the various sign redesign alternatives that were developed. The purpose of the laboratory evaluations was to select the most promising sign redesign alternatives for simulator testing and field verification. The simulator was used to test for potential problems in viewing the new designs in an active or moving environment. Closed field testing was used to verify the simulator results.

It was originally estimated that there would be three design alternatives for each of the 30 problem signs, or a total of 90 new signs to be studied in the laboratory along with the 30 existing problem signs. However, the process of developing sign redesign alternatives was especially fruitful. There were 163 candidates developed in the redesign phase.

It became necessary to deviate from the proposed evaluation procedure. It was originally proposed that a single laboratory screening procedure precede the simulator comparison of the most promising designs. Because of the large number of candidates, two separate laboratory procedures were conducted to select the most promising sign designs for simulator testing. The two laboratory studies involved a screening procedure and a selection procedure. The screening procedure eliminated those sign redesigns that were the least effective. The selection procedure identified the sign design that was the most promising. After

* The "simulator" is the FHWA Highway Driving Simulator (HYSIM), which is described in appendix D.

each of the most promising design candidates was compared to its existing counterpart, final recommended changes to the MUTCD were made.

SCREENING PROCEDURE

Since the purpose of this portion of the laboratory study was to identify the least comprehensible sign designs, the screening procedure looked for relatively large differences in motorist comprehension. The hypothesis tested was that the driver understanding level of some of the sign designs is lower than the driver comprehension level of the other signs. The measure of effectiveness was the accuracy of the subjects' meaning/comprehension response to each design. The procedure used was a paper-and-pencil test.

Test Subjects

Because this initial laboratory procedure made the first cut of the various sign redesigns, it was important that the subject population be representative of licensed drivers of both sexes and all age groups and for a variety of geographical settings. Subjects were selected from among those individuals renewing drivers' licenses at local Department of Motor Vehicle (DMV) offices. Figure 1 illustrates the demographic distribution of the subject population. Test subjects were selected from an urban area (Baltimore, Maryland), a densely populated suburban area (Arlington, Virginia), a less densely populated suburban area (Fairfax, Virginia), and a rural area (Warrenton, Virginia). As shown in the figure, there were three age categories (<30, 30 to 50, and >50) for both sexes. By testing 10 subjects in each age/sex category in each of the four geographic areas, a total of 240 subjects were tested.

	AGE		
	Less than 30	30-50	50+
Male	10	10	10
Female	10	10	10

URBAN

	AGE		
	Less than 30	30-50	50+
Male	10	10	10
Female	10	10	10

SUBURBAN
(densely populated)

	AGE		
	Less than 30	30-50	50+
Male	10	10	10
Female	10	10	10

SUBURBAN
(less densely populated)

	AGE		
	Less than 30	30-50	50+
Male	10	10	10
Female	10	10	10

RURAL

Figure 1. Subject demographic distribution (total N=240).

Laboratory Procedures

Test booklets containing about 40 sign redesign options were prepared. Five sets of materials were needed to include all the sign redesigns and the existing signs. Each page included a picture of the sign and the question "What do you think this sign means?" Alternative formats were pilot tested.

The role of stimulus context was also examined during pilot testing. Two sets of pilot test materials were prepared. One set showed the sign stimuli in the context of a generic highway scene, the other had just the signs. A total of 24 subjects (2 from each age and sex group) were tested to determine if sign context cues affected subjects' responses. The responses from the pilot test booklets were reviewed and each response was judged as correct or incorrect. A value of the mean number of correct answers was calculated for each subject group (those shown the signs in a highway context and those who were not). A t-test showed that there was not a significant difference between the means of the subject populations. However, since other research has shown that using a highway context format produces greater levels of comprehension (Wilson & Williams, 1984), it was decided to use the highway context format for testing. Four different scenes were used. One depicted a suburban neighborhood street, another was a two-lane one-direction parkway, a third was a three-lane one-direction parkway, and the fourth showed a continuous two-way left turn lane. A sample of each scene as used in the test booklets is shown in appendix E.

The entire procedure was then pilot tested at local DMV offices to assure that the test length was appropriate, the format was understandable, and the subjects were able to provide usable data.

Results

A numerical coding scheme was created so that the subjects' answers could be tabulated and analyzed. The coding scheme attempted to preserve the gist of the original responses while giving the flexibility to cluster the data in several different categories without losing the ability to expand and contract it into new tabulations.

A two-digit number was assigned to each response, as shown in table 3. The first digit assigned the response to a general category of answer. The second digit identified individual responses within each category. For example, the Advance School Crossing Sign (S1-1) may have prompted one subject to give the response, "school crossing ahead." This would be considered a correct answer and could have been coded 01. Another subject may have responded to the same sign with the answer, "school zone." This would also be correct, but to keep its identity separate from the "school crossing ahead" responses, it would be coded 02. Someone else may have responded to the same sign, "woman crossing the street" (an actual response). This answer would have been considered bizarre and coded 40. The next answer which could be considered bizarre would have been coded 41. Every distinct response was given its own code number. This is not to say that each subject's response received its own code number. Many subjects gave the same answers, verbatim. While many others gave answers which were considered to have the same gist. All of these similar replies were assigned the same code number.

Table 3. Subject response code.

Code #	Category	
0X	Correct	Right
1X	Nearly Correct	
2X	Conceptually Close	Wrong
3X	Incorrect	
4X	Bizarre	
5X	Dangerously Incorrect	
6X	Confused with Existing Sign	
7X	Overflow	
8X	Overflow	
9X	Unknown	
00	No Response/Don't Know	

Once the individual codes were set, they were used throughout all of the testing procedures. The code is included in appendix F.

In an attempt to facilitate decision making, a super-hierarchy was established over the categories. Any answer considered correct or nearly correct was grouped into the super category of "right," and all other responses formed the super category of "wrong." While the categories were useful for noting trends in responses and breaking ties among promising sign candidates, the decision to use a sign was based on how many people could give a functionally correct (right) interpretation of the sign, as discussed in chapter 3.

Since there were so many signs produced from the redesign effort, the signs, both standard and experimental, were sequentially numbered to simplify their identification for discussion purposes. The identification numbers are shown in appendix C. They are adjacent to the sign on the upper left-hand side.

The decision regarding which signs to further test and which signs to eliminate was based on many different factors. The overriding factor was the percentage of test subjects who gave a functionally correct definition to the sign. This percentage is shown in appendix C at the lower right side of each sign. Contingency tables of the number of "right" and "wrong" answers for each sign were used to see if there was a dependence between sign candidate and subject response. The chi-square statistic was analyzed at the 0.05 level of significance.

Other factors were also considered when deciding which signs would receive further testing. Many of the signs used similar symbolic elements. The apparent strengths of those specific elements influenced the decision to include some of the poor performing signs because similar "sister" signs did so well. Often two signs which performed equally well were recognized as depending on a single strong element and were redesigned into one sign. Some factors were sign specific. A discussion of the individual results for each sign follows. Unless reported otherwise, all of the statistical analyses showed significant results (at the 0.05 level).

W1-2 Curve Sign (Test Signs 1-5). The existing sign was correctly identified by 40 percent of the subjects. Signs #3 and #5 were recognized by 56 percent and 46 percent of the subjects, respectively. Signs #2 and #4 were easily the poorest performers, being correctly identified by 28 percent and 25 percent of the subjects, respectively. The major weakness in Signs #2 and #4 was the use of dotted lines as part of the symbol. This led many subjects to believe the signs had something to do with passing or no passing zones. The use of perspective in Signs #2 and #4 also prompted many subjects to think the signs showed an uphill or downhill section of road. Since Sign #3 did so well relative to the other signs, it was decided to test the Canadian curve sign which was used as a basis for the design of Sign #3. The Canadian sign is the same as Sign #3 with the exception of the wide black borders. It was decided to eliminate Signs #2 and #4 from further testing and to add the Canadian curve sign for testing in the next phase.

W1-5 Winding Road Sign (Test Signs 6-10). The statistical analysis showed that there was no significant difference among the signs in this group. Unfortunately, a decision about which signs to eliminate had to be made. With the exception of the existing sign, Signs #8 and #10 were the poorest performers. This result cannot be considered significant, but Signs #8 and #10 are the same style as Signs #2 and #4, which have already been eliminated. Signs #8 and #10 also had a greater percentage of dangerously wrong answers than the rest of the signs (e.g. passing/no passing, uphill/downhill). So for consistency in the next test phase and use of the safest designs, Signs #6, #7, and #9 were retained for further testing.

W1-3 Reverse Turn Sign (Test Signs 11-15). The existing sign, the "border" sign (#13), and the "wide tail" sign (#14) did the best among the signs tested. Here a different type of hybridization was used on Sign #12. Two advisory speeds were placed on the sign to address the varying severity problem brought up in Chapter 3. While this seemed like a logical solution to that problem, it failed miserably. Few subjects interpreted the sign as two curves/turns with two advisory speeds. Many thought the numbers meant speed limits on the tangent sections of road entering the curve and leaving the curve. This sign, along with Sign #15, was eliminated from further testing.

W1-1 Turn Sign (Test Signs 16-20). The existing sign, "border" sign, and "wide tail" sign performed the best; therefore, these signs were retained for further testing. Again the same type of problem answers surfaced with Signs #17 and #19 as did with Signs #2 and #4, and these signs were eliminated.

W1-4 Reverse Curve Sign (Test Signs 21-25). There was no relationship shown between the signs and correct response rate at the chosen level of significance. The signs in this group did uniformly bad. Although Signs #24 and #25 did the best, they were eliminated from further testing for two reasons: (1) since the results failed to meet the statistical test, they could be attributable to chance, and (2) since the "border" and "wide tail" signs performed better in other cases where the results were significant, it was felt that they should remain as part of the test group here as well.

S1-1 School Advance Sign (Test Signs 26-34). Signs #29 and #32 were the two most recognized candidates, being recognized by 67 percent and 52 percent of the subjects, respectively. In reviewing the results it was also shown that more subjects

associated Sign #29 with a school than they did Sign #32. More frequently Sign #32 was associated with children, but not schools or school children. Therefore, it was decided to retain Sign #32 along with Sign #29 and the current standard (#26) for further testing, but to use the older looking figures from Sign #29 on Sign #32. When seeing the subsequent analysis of the Yield Ahead Sign (W3-2a) it became apparent that by simply reversing the top and bottom placement of the key pictographic element (the Yield Sign) and the arrow signifying ahead, significant changes in comprehension level occurred. In order to put these results to a more vigorous test, it was decided to use alternate placement of figures and arrows on other signs where part of the total message was the concept of ahead. Besides testing Signs #29 and #32, similar versions of these signs with the positions of the arrows reversed (top and bottom) were tested as well.

S2-1 School Crossing Sign (Test Signs 35-39). Each candidate outperformed the existing sign. The new signs emphasized the crosswalk lines more than the standard; therefore, it was decided to retain Sign #38 only for further testing since the crosswalk depiction in that sign did the best. As with the Advance School Sign (S1-1) candidates, the smaller figures of children were not strongly associated with a school situation. Therefore the small children were replaced by the larger figures of children for testing in the next phase.

S3-1 School Bus Stop Ahead (Test Signs 40-44). The existing sign (#40) was the most correctly recognized sign. The next most recognized signs were #42 and #44. These signs have very similar designs in that they both use arrows to signify the concept "ahead." It would seem to be a matter of preference as to which sign should be tested further, but as seen in the results of the Yield Ahead Sign (W3-2a) the arrow placement can have some effect

on the results. using a black foreground/horizon area on Sign #44 did cause some figure/ground problems, therefore it was determined to use a design similar to #44. It would retain the arrow, but not have the black area around the arrow. The decision was made to retain for further testing the standard sign, Sign #42, and the modified Sign #44.

W11-2 Advance Pedestrian Crossing Sign (Test Signs 45-52). The results for this group of signs proved to be somewhat confusing. Sign #52, which scored the highest, used elements which caused some problems on other signs. The arrow embedded in the lower black area proved to be a problem for Sign #44, School Bus Stop Ahead, as well as Sign #51 in this group. The use of two pedestrian figures caused some subjects to confuse signs where that element was used with the school signs (i.e., use of two human figures on each sign). Nevertheless, Sign #52 was correctly identified by 78 percent of the subjects tested. It would seem logical that the rest of the signs be eliminated and Sign #52 be retained for further test. However, since this is the only case where these elements did so well and in an attempt to maintain some design consistency, two new designs patterned after the School Advance Sign candidates were used for further testing.

W11A-2 Pedestrian Crossing Sign (Test Signs 53-56). The statistical analysis for this group showed that the results were not significant. This was not especially surprising in that all of the candidates were slight variations from the standard. The only real difference was the use of two pedestrian figures and emphasized crosswalk lines. As mentioned in the discussion of the Advance Pedestrian Sign (W11-2), use of two pedestrian figures proved to be a detriment rather than an aid to the sign's ability to be understood in that the sign was often confused with

the school signs (S1-1, S2-1). This is due to the fact that the school signs use two pedestrian figures as well. Therefore, it was decided to retain the standard and one new sign with one pedestrian figure and emphasized crosswalk markings.

W8-3a Pavement Ends Sign (Test Signs 57-62). Signs #58 and #60 had nearly equal levels of comprehension. This may be due in part to the fact that they are similar designs. It was decided to combine the profile and different road textures into one new sign to be used for further testing. The new design would also use only one vehicle profile because Sign #58 caused many subjects to believe the sign had something to do with following distance or tailgating. Sign #61 also appeared to show some promise, being recognized by 48 percent of the subjects, and it was retained for further testing along with the existing standard sign (#57).

W8-4 Soft Shoulder Sign (Test Signs 63-67). For literate English-speaking subjects, it would appear that word signs provide an effective means of communicating to the driver as evidenced by the performance of the standard sign from this group. Since the majority of the correct answers for Sign #63 was the parroting back of the word message by the subjects, some doubt is cast on how well the intended meaning of the sign is understood. But the symbol candidates faired so badly that it seems there may not be an acceptable way of depicting this sign symbolically. The real problem associated with the sign may be addressed better through education than by counting on a new sign as a panacea. Therefore, it was decided to no longer test the standard or any of the design options.

W8-4b Low Shoulder Sign (Test Signs 68-73). With this group of signs, as with the Soft Shoulder group, it is difficult to

pictorially represent the shoulder area of the road. The relatively poor level of comprehension shows this to be true for this sign group. Sign #69 performed the best, but visually and cognitively it is difficult to "see" the small notch which represents the change in height at the shoulder. Sign #66 in the Soft Shoulder group was often mistakenly recognized as a Low Shoulder Sign. It was thought that by combining Signs #66 and #69 a better performing candidate would be produced. This new sign and the existing standard were the only signs retained for further testing.

W8-4c Uneven Pavement Sign (Test Signs 74-79). The signs in this group were of two basic designs. One design showed a single vehicle crossing over different pavement heights (Signs #74, #75, and #78). The other style showed two vehicles, each on different pavement heights (Signs #76, #77, and #79). The best performer in each group (#75 and #76), along with the standard (#74), were retained for futher testing.

W5-2a Narrow Bridge Sign (Test Signs 80-88). Here one group of signs did considerably better than the remaining candidates and standard. Signs #85, #87, and #88 all had a "wavy line" element added to the plan view of the roadway and bridge. This was done in the hope that subjects would recognize the lines as water and, therefore, recognize the sign represents a bridge. While many roadway bridges do not cross water (i.e., they may cross railroad tracks or highways), it was thought that it is not necessary for motorists to know what they are crossing over, but it is important that they know they are approaching a narrow bridge. It was decided that Sign #87 would be retained for further testing. At the request of FHWA, similar signs depicting rail and highway bridge crossings were prepared to be tested with Sign #87. These three signs, along with the standard (#80), were tested in the next phase.

W20-4 Advance One Lane Road Sign (Test Signs 89-95). As with the School Bus Stop Ahead Sign (S3-1) and the Soft Shoulder Sign (W8-4), a majority of the correct answers for Sign #89 was the repetition of the word message on that sign. Again, it is difficult to tell if the subjects had a true understanding of this sign. Signs #90, #91, #92, and #93 were of a similar design and they scored better than the alternate design type of Signs #93 and #95. Since perspective views caused some recognition problems in other sign designs, it was decided to use Sign #91 rather than Sign #94 for further testing. In testing other signs (see Emergency Zone Sign Report, appendix G) it was found that an "X" symbol is an effective way to communicate road or lane closure to motorists. Based on this finding, it was decided to test an alternate design of Sign #91 with an "X" in place of the hatching in the right lane. Some concern was expressed about potential visibility problems with a sign consisting of such a large black area. In order to eliminate this concern, the test candidates were redesigned to be "negative" versions.

W4-2 Lane Reduction Transition Sign (Test Signs 96-101). The signs in this group were mostly a variation on the standard sign (#96). Arrows and lane markings were used to show an actual lane drop rather than just a narrowing of the road. Sign #101 used a black roadway area to show the lane drop, and performed quite well (66% correct), but concern about potential visibility problems eliminated it from further testing. Although Sign #98 performed the best of all the new sign candidates (76% correct), some concern was expressed over the ability of motorists to see the small arrow. It was decided to retain Sign #97 and the standard for further testing.

W3-1a Stop Ahead Sign (Test Signs 102-108). Here the two best performers were the standard sign (#102) and Sign #108.

They were correctly recognized by 86 percent and 92 percent of the subjects, respectively. The slight difference in recognition level could hardly be called significant, but this is not surprising because the designs are so similar. Both signs were retained for further testing for reasons which will become clear in the discussion of the Yield Ahead Sign (W3-2a) results.

W3-2a Yield Ahead Sign (Test Signs 109-115). As with the Stop Ahead Sign (W3-1a), the two most recognized versions of this sign were the standard (Sign #109) and a top-bottom reversal of the standard (Sign #114). What is especially surprising here is that although the designs are very similar there is a wide variation in recognition levels. The new sign outperforms the existing sign by 19 percent. This caused some reconsideration about arrow placement on signs where arrows are used to denote "ahead" (e.g., School Advance Sign, Stop Ahead). It was decided to retain Signs #109 and #114 for further testing and consider testing all "arrow" signs with the arrow in top and bottom positions.

W12-2 Low Clearance Sign (Test Signs 116-121). There were three sign types in this group. One group made use of arrows and numbers only to convey the clearance message (Signs #116, #117, and #119). Another added front or rear views of trucks to help motorists understand this sign (Signs #120 and #121). The last substituted a profile view of a truck for the other truck views as part of the pictograph (Sign #118). Sign #118 was recognized by all the subjects tested. This was the only sign, standard or new candidate, to do so in this test phase. Some concern was expressed over the visibility of the smaller (relative to the standard) clearance height numbers and the use of large amounts of black on this sign. This was taken into consideration, and the sign was redesigned to have less black areas and a supplementary

plate with the clearance height was added. The same modifications were made to Sign #120, and these signs along with the standard (Sign #116) were retained for further testing.

W6-2 Divided Highway Ends Sign (Test Signs 122-129). In order to make a choice about which signs to keep, it was decided to pick a sign which addressed the end divided highway/begin highway confusion. Sign #125 uses perspective effectively to deal with the problem, but as seen with other perspective signs, potential interpretations of a narrowing roadway made this an unviable alternative. Sign #124 is the only other real attempt to deal with the directionality problem, so it and a version without the border areas were retained for further testing along with the standard (Sign #122).

R3-9a Two Way Left Turn Only Sign (Test Signs 130-138). The statistical analysis of the results for the signs in this group was not significant. All the candidate signs relied on the addition of the lane pavement markings to aid motorists' understanding of this sign. This did help, since all the candidates performed better than the existing sign (#130). The new sign which performed the best (Sign #133) was eliminated because of its similarity to the existing post-mounted version of this sign and its heavy reliance on words. Therefore, it was decided to retain Sign #131 and the standard for further testing.

R4-7 Keep Right Sign (Test Signs 139-144). The standard sign (#139) outperformed all of the new candidates, but either is often confused with the Begin Divided Highway Sign (W6-1) or the arrow element of the sign is interpreted as representation of horizontal alignment. A new sign similar to Sign #141 using an outwardly curving arrow, similar to the one used in Sign #143, will be tested along with the standard.

W4-1 Merge Sign (Test Signs 145-151). For this group every new candidate performed worse than the existing sign (#145). Since the standard performed so well, it was decided that it no longer be included as a problem sign.

W4-3 Added Lane Sign (Test Signs 152-157). The statistical analysis for this sign group showed that the test results were not significant. This is not suprising, considering the poor performance by all of the signs including the standard (Sign #152). Not one subject could correctly identify the existing sign. The new signs did not fare much better. Sign #156, while performing the best (10% correct), was eliminated because of previously mentioned problems with perspective signs. The next best performer, Sign #157, was retained for further testing, along with the standard and the existing Merge Sign (Sign #152). Sign #145 was included with the group because the Added Lane Sign is most often mistaken for a Merge Sign.

W20-7a Advance Flagger Sign (Test Signs 158-164). The statistical analysis showed that the test results were not significant for this group of signs. The outcome showed little variation between the standard (Sign #158) and the best performing candidate (Sign #160) (78% correct and 86% correct, respectively). Both signs were retained for further testing because it was thought the element of a moving flag may aid motorists' understanding and Sign #160 was representative of that design type.

W21-1a Worker Sign (Test Signs 165-171). The results of the test for this group were not statistically significant. Even though the results for the new signs, with the exception of Sign #171, were higher than the standard (Sign #165), the existing sign performed relatively well when compared to other standard signs.

Therefore, it was decided to retain a candidate which was similar in design to the standard. Sign #166 was chosen and received further testing along with the standard.

W2-2 Cross Road Sign (Test Signs 172-179). This is a definite case of "if it ain't broke, don't fix it." A mistake was made in identifying the standard as a problem sign, and the sign has been eliminated from further consideration as a problem sign.

W7-1 Hill Sign (Test Signs 180-186). In this sign group there were two types of hill symbol. One was a wedge-shaped hill (Signs #180, #181, and #183). The other was a dip-shaped hill with an arrow (Signs #182, #184, #185, and #186). The dip hill without the word "hill" did not perform well. In retrospect, it was counterproductive to add words to symbolic signs; therefore, all dip hill signs were eliminated from further consideration. The results also showed that using a single vehicle provided less confusion to motorists. Sign #183 prompted subjects to make responses concerning following distance or tailgating. The van figure for Sign #181 was replaced by a generic automobile figure, since the different vehicle types used on the candidate signs had little effect on subjects' responses. The redesigned Sign #181 and the standard (Sign #180) were retained for further testing.

W8-5 Slippery When Wet Sign (Test Signs 187-193). All of the new sign candidates did better than the existing sign (#187). Sign #188 was the leading candidate (96% correct). Its next closest competitor (Sign #193) was similar in design to Sign #192, which was the poorest performer of the new signs. Therefore, it was decided to retain only Sign #188 and the standard for further testing.

CANDIDATE SELECTION

The second laboratory procedure selected the best redesign candidate for simulator testing. The procedure was a test of sign meaning with the emphasis placed on identifying potential sources of confusion between the various candidates for each sign, within sign families, and across all signs. In order to determine the level of detail needed to make this determination, a non-directive laboratory procedure was used.

Test Subjects

Subjects were selected from the age/sex categories previously described. Again, drivers from DMV stations were used. Results of the screening procedure showed that there was no significant variation between the test results at the four testing locations. Therefore, it was decided to test at only one location for this procedure. The Fairfax, Virginia location was used.

Laboratory Procedures

The subjects were shown pictures of design candidates superimposed over pictures of an actual street/roadway setting and asked to tell the meaning of each sign. The test instrument was a booklet containing 17 signs. Again, five sets of booklets were needed to include all the signs chosen for testing in this phase.

Some of the responses from the screening procedure indicated that some subjects were "reading" too much or too little into the highway context scenes. They appeared to be too generic. In an attempt to correct this, the generic scenes were tailored more to the sign which was to be placed in the scene. The new scenes, as used in the test booklets, are shown in appendix H.

Since many of the written responses from the screening procedure had meanings which could have been interpreted many ways (e.g., schoolbus - stops ahead or school - bus stops - ahead), it was decided that after the subjects filled out the test booklets they would be debriefed about their replies. The debriefing had two approaches: one used non-directive questions to clarify vague responses or elicit additional information, and the other asked direct questions about parts of the symbol or why a certain reply had been made. Those conducting the debriefing attempted to gather as much additional information as possible with the non-direct approach before beginning any direct questioning.

Results

The same numerical coding scheme used to tabulate the data from the screening procedure was used to analyze the results of the selection procedure. Information gathered from the debriefings was used to clarify subjects' written responses. This allowed the experimenters to assign specific responses to gist response codes with a greater degree of confidence than in the analysis of the screening procedure results. The debriefing also provided insight into problems dealing with communication by sign and into the effectiveness of that communication which heretofore had not been identified. Upon probing subjects about some answers which were considered "incorrect" in the screening procedure analysis, it was found that these subjects did have a functionally correct interpretation of the sign but failed to express it in writing. Therefore, many of the answers previously considered incorrect were counted as correct answers. These response codes are circled on the code sheets in appendix F.

The signs were sequentially numbered for discussion purposes. These numbers are placed near the upper left hand side of the

sign. The numbered sign and respective percentage of functionally correct (right) answers are shown in appendix I and figure 2.

Through the selection process information was derived as to which sign candidate had the best cognitive value. This decision was based on the percentage of "right" answers given for each sign and additional information gathered from the debriefing. The results were checked using contigency tables. The chi-square statistic was analyzed at the 0.05 level of significance. Unless reported differently, all of the analyses showed significant results (at the 0.05 level). A discussion of the individual results for each sign follows.

W1-2 Curve Sign (Test Signs 1-4). The best performer in this group was Sign #3 (92% correct). The existing sign did quite well also (84% correct). One problem did surface during the debriefing with this sign. It seems that there is a personal conceptual stereotype for a section of road which is not a tangent section. What this means is that everyone has his or her own way of describing a piece of curved roadway. For one person, if the road is not straight it is curved. The degree of curvature is sometimes indicated by an adjective such as "right angle" or "little," or sometimes degree of curvature is not noted at all. For someone else, any type of curve is a turn (e.g., a sharp turn, an easy turn). When shown the Curve Sign and asked to tell what the sign means, a subject would reply, "It's a turn." If asked to do the same for a Turn Sign, he would answer, "It's a turn." If the subject was shown both signs side by side and asked if he noted a difference between the two signs, he would say, "Well they're both turns, but this one (pointing to the Curve Sign) is a longer turn." Asked to elaborate on what a longer turn was, he would reply, "It's not as hard as the other one (the Turn Sign)." One begins to sense that the actual difference between

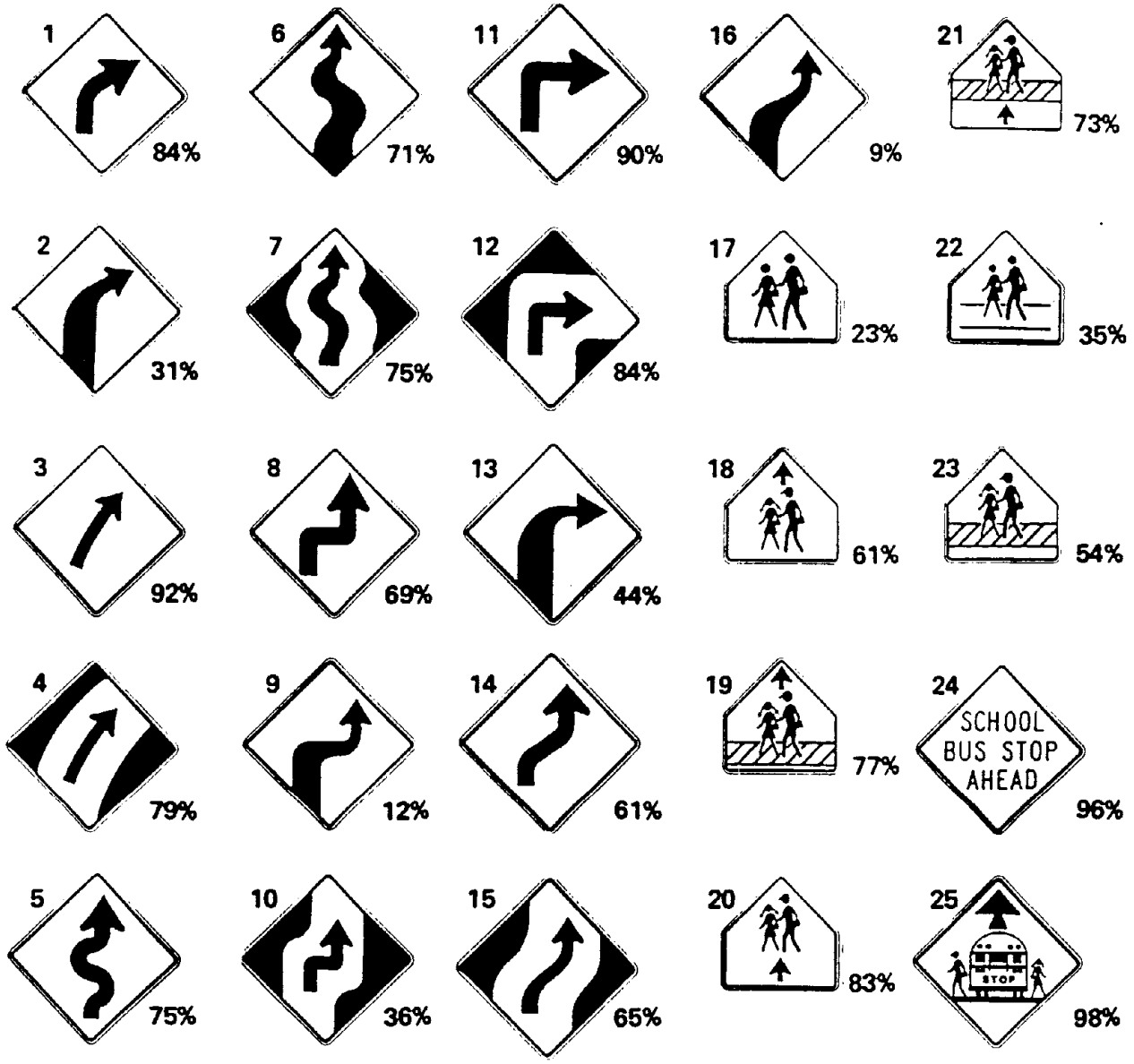

Figure 2. New sign design--step 3.

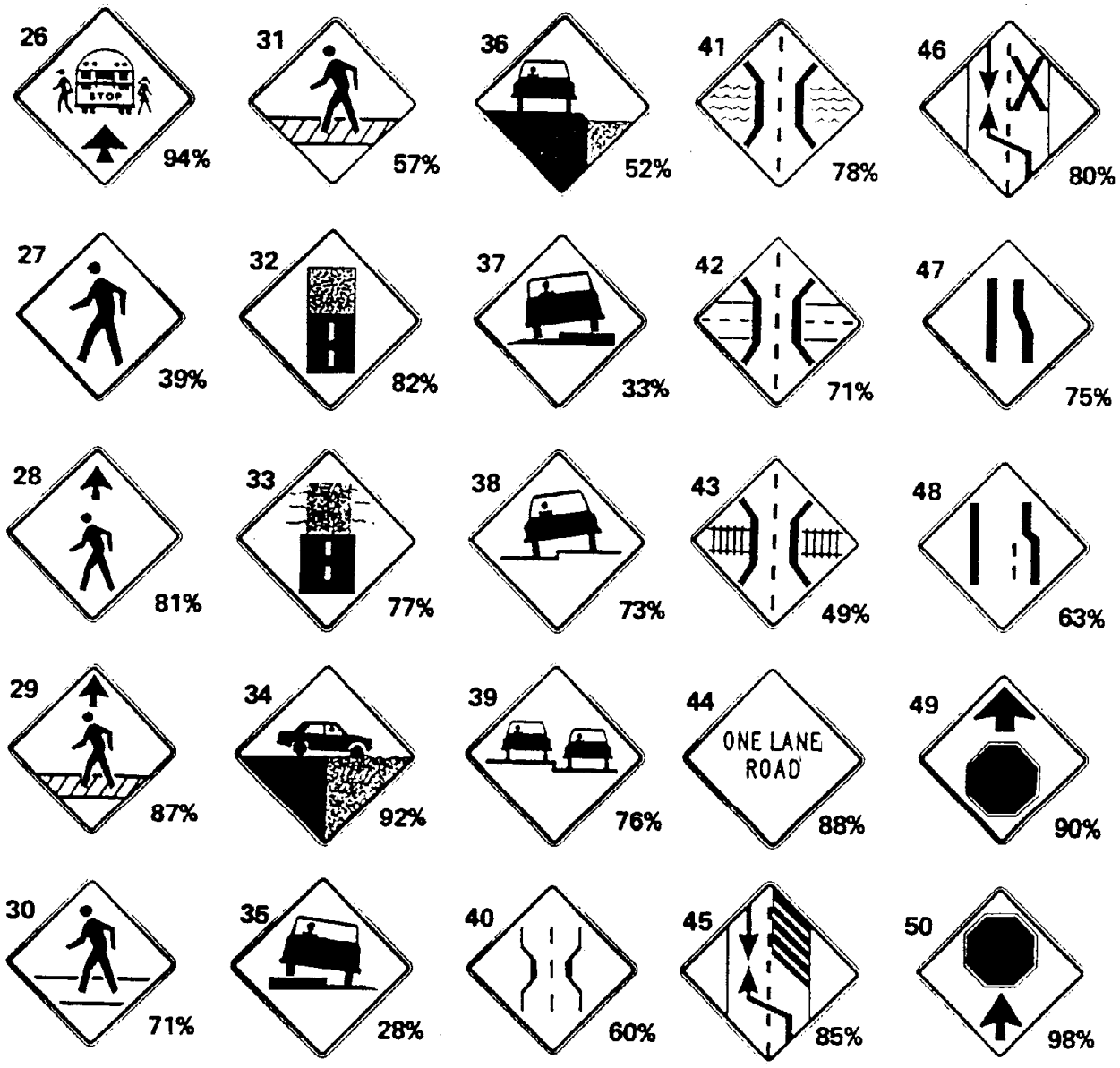

Figure 2. New sign design--step 3 (continued).

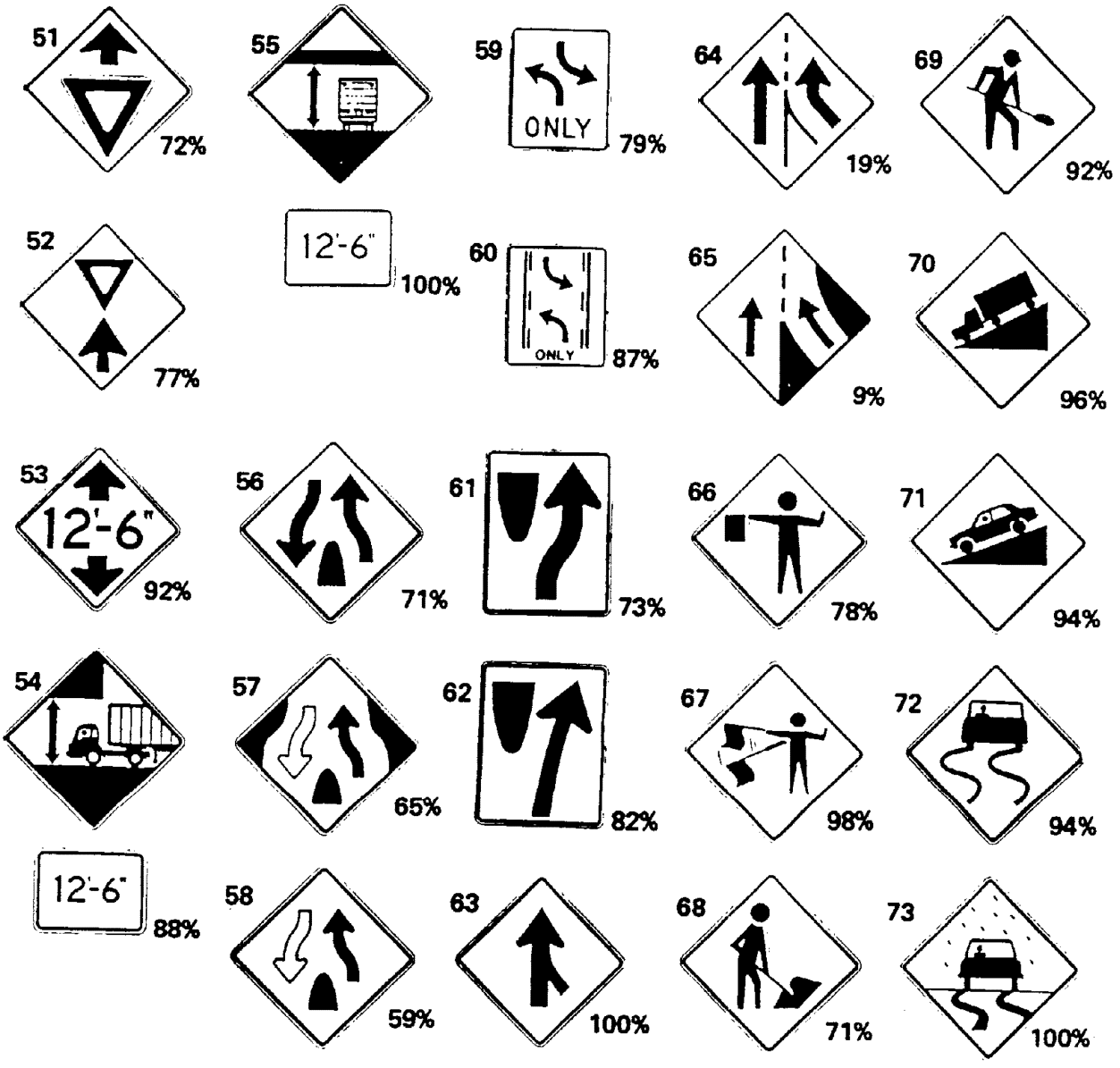

Figure 2. New sign design--step 3 (continued).

these signs may be noted by different drivers, but with replies such as this it is difficult to say if one sign communicates the idea better than another one.

W1-5 Winding Road Sign (Test Signs 5-7). The results for this group of signs was not significant. There are many different descriptions given to these signs. Many of the descriptions do not match the MUTCD version, however one begins to feel that the idea of many curves is understood. The added concepts of direction (i.e., first curve-right, next curve-left) and number of curves to expect (3 or more) do not appear to be well understood.

W1-3 Reverse Turn Sign (Test Signs 8-10). The existing sign was correctly recognized by 69 percent of the subjects. This was by far the best of the signs tested. As with the Curve Sign (W1-2), many of the subjects use the terms "reverse turn" and "reverse curve" or variations on those interchangeably. A typical written response for the Reverse Turn sign might be, "Road curves and then goes straight." When asked how many curves he would expect to see, the subject would reply, "Two." If shown the Reverse Turn and Reverse Curve signs side by side and asked to note any difference between the two, the subject would answer, "This one (Reverse Turn) is sharper." Again, one suspects that the gist of the intended message is being received, and since there are not many accounts of accidents in curves where signing is cited as a major cause, this suspicion may be grounded in fact.

W1-1 Turn Sign (Test Signs 11-13). The standard sign was the best performer within this group (90% correct). The examples cited for the Curve Sign, interchangeable use of the terms curve and turn, occurred during debriefings about this sign also.

W1-4 Reverse Curve Sign (Test Signs 14-16). In this sign group Sign #15 was correctly identified by 65 percent of the subject group. This was the highest percentage within this sign set. As with the Reverse Turn Sign, the information is sketchy as to whether the message to be conveyed by this sign is fully understood.

S1-1 School Advance Sign (Test Signs 17-21). Sign #20 was the sign most often correctly identified (83% correct). During the probing procedures, replies to certain questions caused some concern over whether the "advance" and "crossing" concepts are understood at all. An example of this would be when a subject was shown Signs #18-#21 he might give a written reply, "school crossing." If the subject was asked what he thought the arrow on the sign meant, he would reply, "Ahead. But of course it means ahead, all these signs (in the test booklet) mean ahead. Don't they? You wouldn't be warning me about something behind me, would you?" When shown the School Crossing Sign this same subject would give the written reply, "School crossing." Since there is no arrow on the crossing signs (Test Signs #22 and #23), there is no way to prompt the subject on the inferred concept of ahead. If one of the test advance signs (Test Signs #18-#21) was shown side by side with either of the crossing signs, and the subjects were asked to note any difference between the two, the concept of having two signs to warn about the same thing is so foreign to them that they would invent new interpretations for the advance sign (e.g., "School children walk along this road"). This was done despite the fact that they had already interpreted the sign differently. Again, it seems that part of the message does get through, but it is difficult to see if it is the exact desired message.

S2-1 School Crossing Sign (Test Signs 22-23). Sign #23 was recognized more than the standard sign, but based on the findings discussed in the previous section it is difficult to say if either sign should be used as a school crossing sign.

S3-1 School Bus Stop Ahead Sign (Test Signs 24-26). The results for this group of signs were not statistically significant, but all three signs were comprehended by at least 94 percent of the subjects tested.

W11-2 Advance Pedestrian Crossing Sign (Test Signs 27-29). Sign #29 was the most recognized (87% correct), but during subject debriefings the same situation which was described in the School Advance/Crossing results occurred with the pedestrian signs. The Advance Pedestrian Sign is mistaken for the Pedestrian Crossing Sign and both are thought to mean "Pedestrians crossing up ahead."

W11A-2 Pedestrian Crossing Sign (Test Signs 30-31). The results for this group of signs were not statistically significant. The difficulty in discerning statistically between the two signs tested is compounded by the failure to grasp the concept that there is an advance warning and another sign placed at the crosswalk itself. As with the school signs and the Advance Pedestrian Sign, this became apparent during the subject debriefing.

W8-3a Pavement Ends Sign (Test Signs 32-34). The results for this group of signs were not statisically significant. Sign #39 was identified by 92 percent of the subjects, and the standard sign was recognized by 82 percent of the test subjects.

W8-4b Low Shoulder Sign (Test Signs 35-36). The standard sign was recognized by 28 percent of the test subjects, while 52 percent recognized Sign #36. Thirty percent of the subjects interpreted the standard sign as "uneven pavement."

W8-4c Uneven Pavement Sign (Test Signs 37-39). Both sign candidates outperformed the existing sign in this group. Signs #38 and #39 were recognized by 73 percent and 76 percent of the subjects, respectively. The standard was recognized by only 33 percent of the test subjects.

W5-2a Narrow Bridge Sign (Test Signs 40-43). Sign #41 was the most recognized of the group (78% correct). A sign of similar design (#42) showing the bridge crossing a section of road was recognized by 71 percent of the subjects. A third sign (#43) showed a bridge crossing railroad tracks. This sign did rather poorly in comparison with the other signs (49% correct), and it was frequently mistaken for a railroad crossing at grade (39% of the subjects). The standard was recognized by 60 percent of the test group.

W20-4 Advance One Lane Road Sign (Test Signs 44-46). The test results for this group of signs were not statistically significant. All three signs in this group were recognized by over 80 percent of the test subjects.

W4-2 Lane Reduction Transition Sign (Test Signs 47-48). The results for this group of signs were not statistically significant. The standard and new sign candidates were recognized by 90 percent and 98 percent of the test subjects, respectively.

W3-1a Stop Ahead Sign (Test Signs 49-50). The results for this group of signs were not statistically significant. The standard and new sign candidates were recognized by 90 and 98 percent of the test subjects, respectively.

W3-2a Yield Ahead Sign (Test Signs 51-52). The test results were not statistically significant for this group of signs. The standard sign was recognized by 72 percent of the subjects, and Sign #52 was recognized by 77 percent of those tested.

W12-2 Low Clearance Sign (Test Signs 53-55). The test results for this group of signs were not statistically significant. All three of the signs were recognized by at least 88 percent of the subjects tested.

W6-2 End Divided Highway Sign (Test Signs 56-58). The results for the signs in this group were not statistically significant. The standard sign (#56) was recognized by 71 percent of the subjects. The two candidate signs (#57 and #58) were recognized by 65 percent and 59 percent of the subjects, respectively.

R3-9a Two-Way Left Turn Only Sign (Test Signs 59-60). The results for the signs tested in this group were not statistically significant. The standard sign was recognized by 79 percent of the test group, and Sign #60 was recognized by 87 percent of the subjects tested.

R4-7 Keep Right Sign (Test Signs 61-62). The results for this group of signs were not statisically significant. Sign #62 was recognized by 82 percent of the subjects, and the standard (Sign #61) was correctly identified by 73 percent of the subject group.

W4-1 Merge Sign (Test Sign 63). This sign was included to be compared with the results of the Added Lane Sign (W4-3). The standard merge was recognized by all of the subjects tested (100% correct).

W4-3 Added Lane Sign (Test Signs 64-65). The results for this sign group were not statistically significant. The standard sign (#64) was recognized by 19 percent of the test group, while Sign #63 was recognized by 9 percent of the subjects.

W20-7a Advance Flagger Sign (Test Signs 66-67). The new candidate sign (#67) was recognized by 98 percent of the test subjects, while the standard sign was correctly recognized by 78 percent of the test group.

W21-1a Worker Sign (Test Signs 68-69). The standard sign was recognized by 71 percent of the subjects, and the new candidate (#69) was correctly identified by 92 percent of the test subjects.

W7-1 Hill Sign (Test Signs 70-71). The results for this sign group were not statistically significant. Both signs were recognized by at least 94 percent of the subjects. It is interesting to note that 46 percent of the subjects felt compelled to add some caveat regarding trucks (e.g., "Trucks check brakes," "Trucks use low gear") in response to the standard sign (#70).

W8-5 Slippery When Wet Sign (Test Signs 72-73). The results for this group of signs were not statistically significant. The standard sign was recognized by 94 percent of the subjects, while Sign #71 was recognized by all the subjects tested (100% correct).

SIMULATOR TESTING

As a newly developed highway safety research tool, the "real world" meaning associated with the absolute value of HYSIM's dependent variables (i.e., recognition distance, reaction time) has not been firmly established. However, the HYSIM was ideally suited for the experimental procedure to evaluate many of the redesign candidates. It was most useful in evaluating those sign redesigns that had potential conspicuity and/or legibility problems.

Since exhaustive cognitive testing was done in the screening and selection procedures, it was thought that the HYSIM procedure would be best used to test the most successful (i.e., likely to replace the standard) sign redesign alternatives where information on legibility, conspicuity, and response time was unknown. It was also thought that the HYSIM could be used to examine the curve/turn problem and the advance/crossing problems associated with the school and pedestrian signs. The signs could be tested in a visually dynamic setting while subjects were engaged in typical driving tasks (operating controls, tracking, visual scanning). The purpose of the simulator tests was to verify that driver performance was not degraded by any of the new signs relative to current signs. Also, driver comprehension of the signs in a limited time, with task loading, could be assessed.

Testing Procedure

The FHWA simulator (HYSIM) is described in detail in appendix D. A driving scenario from a previous study was used to minimize simulator reprogramming time. Signs from this project replaced signs used in the previous study.

Stimuli

The visual scene consisted of computer-generated lines, white or yellow as appropriate, denoting edge and center lines, exit or entrance ramps, and crossroads. The roadway configuration followed the distances, curvature, and number of lanes found in the real-world roadways simulated. The only landmarks or other visual cues were road name signs at major intersections and guide signs or route markers as needed for drivers to follow the route.

The driving scene was depicted at night, so headlights were portrayed and the test room was in darkness. Subject drivers were seated in a full-size car that had instrument panel lights. All controls, steering, and pedals operated as if driving in the real-world.

The signs tested were selected on the basis of the significance of the sign message to safe performance or the need to clarify or verify earlier results, or to resolve questions about driver response to signs. Two types of tests were conducted within the simulator drive.

1. Current and new design signs were compared.

2. Current signs without any comparison were inserted as distractors and to assess their recognition distances relative to other warning signs.

The signs tested in each group are listed in table 4. For the first type of test the current sign design was compared to a new design selected based on results from the previous study.

Table 4. Signs listed by type of test.

Current vs. New	Current Signs Without a New Design Comparison
School Advance Warning	Right Curve
School Crossing	Left Curve
Pedestrian Advance Warning	Right Turn
Pedestrian Crossing	Left Turn
Narrow Bridge	Cross Roads
Lane Added	Deer Crossing
Yield Ahead	
Stop Ahead	
Slippery When Wet	
Clearance	
Pavement Width (lane drop)	

During a simulated drive subjects saw each of the 29 signs. Half of the subjects saw signs that were in one order; the second half saw signs in a different order. These orders were used to minimize order effects, e.g. fatigue, familiarity. Subsequent data analysis gave no indication of order effects.

Test Subjects

Thirty-three licensed drivers volunteered to serve as paid subjects. Seventeen subjects saw signs in Order 1 and sixteen saw Order 2. Equipment malfunction led to two Order 2 subjects being dropped. Table 5 shows the distribution of subjects by order, sex, and age.

Table 5. Subject demographics.

Age Group	Order 1 (n=17) Male	Female	Order 2 (n=16) Male	Female	Row Totals
16-29	2	3	3	2	10/30%
30-54	5	4	2	3	14/42%
55 & over	2	1	2	4	9/28%
	9	8	7	9	33

The goal of half males and half females was achieved with a 48.5% male/51.5% female distribution. The age distribution obtained was not substantially different from the 25/50/25 percent goal.

Subjects were solicited from a variety of church and social groups around the suburban Washington, D.C., location of the FHWA research center where the HYSIM is housed.

Dependent Variables

Three dependent variables or measures of effectiveness (MOEs) were collected during the simulator drive:

- Recognition Distance--Distance in 50-foot increments, from the point signs were exposed to subjects until they flicked the high-beam stalk indicating they saw and knew the meaning of the sign.

- Speed--The average speed of the vehicle in feet per second for each 50-foot increment before, during, and after each sign presentation. Speed change was calculated as mean speed in the two zones (50-foot increments) preceding recognition minus the two zones following recognition.

- Response Accuracy--After the subjects indicated recognition of a sign they verbally described the sign's meaning or message. The experimenter scored the response using the codes developed in the earlier studies. These codes are listed in appendix F. All data were collected on the HYSIM computer.

Procedure

Subjects arrived at a scheduled time. They were tested for color vision and static visual acuity and all met the 20/40 corrected criterion for most state drivers licenses. Instructions were read to the subjects. They were introduced to the simulator room and executed a practice drive. After last-minute questions were answered, the 25-35 minute test drive began.

As the subjects drove, signs appeared along the roadway. Signs were presented at the visual equivalent of 950 feet between driver and sign. A few signs, because of roadway sight distance limitations, e.g., horizontal curvature, were seen at 550 feet. Using the zoom lens the sign grew "closer" as the driver approached it. Two hundred feet before reaching the sign, it "went off." Subjects were urged to follow the speed limit.

Results

Data were edited and transferred to a main frame computer with BMD statistical software. Repeated measure analysis of variance was used with recognition distances. Analyses of variance and covariance were used for the speed data. Here, post-recognition speed was analyzed separately and pre- and post-recognition speed (speed change) was tested with the ANCOVA program. Response accuracy was a calculation of percent correct and contingency tables were tested with the McNemar test. The results are discussed for each type of test conducted.

Comparison of Current and New Design Signs

In general, there were few speed, recognition, or comprehension differences between these signs. Table 6 summarizes the results. With the following exceptions, the results suggest that the new signs perform as well as the current sign designs.

- School Advance Warning--the new design has some performance but not comprehension advantage.

- Pedestrian Advance Warning--the new design exhibited improved comprehension but not recognition distance or speed change differences.

The fact that the new signs perform as well as the current sign designs is a very encouraging experimental result. Many of the new signs had additional visual detail and/or design factors that were novel to the test subjects. In the laboratory testing it was found that many of the new, more visually complex sign designs produced significantly better levels of motorists' understanding. There was some concern that the superior performance of the new designs in the laboratory might not continue when tested in the more complex environment of a driving simulator. That the new signs performed as well as the old signs, combined with the better cognitive performance of the new signs, indicates that some of the new sign designs are very promising.

Current Signs Without a New Design Comparison

There was considerable interest in the traffic engineering and human factors communities over the distinction between curve and turn signs. Left and right curve and turn signs were tested

Table 6. Simulator study results—current and new sign comparisons.

Signs Being Compared	Response Accuracy	Recognition Distance (ANOVA)	Speed	Comments
School Advance Warning (C) School Advance Warning (N)	10% 13%	- $p > .006$; N sign seen 4.1% before C sign - Group by sign interaction $p > .006$; C sign more consistent	- No statistical difference from pre-sign recognition to post-sign recognition	N has slight performance advantage
School Crossing (C) School Crossing (N)	35% 29%	- Sign by group interaction $p > .02$ - N sign more consistent across groups	- No statistical difference	Lower comprehension of N offsets performance difference
Pedestrian Advance Warning (C) Pedestrian Advance Warning (N)	3% 31%	- No statistical differences	- No statistical differences	Comprehension favors N sign; No performance differences
Pedestrian Crossing (C) Pedestrian Crossing (N)	71% 65%	- No statistical differences	- No statistical differences	No statistical differences between signs
Narrow Bridge (C) Narrow Bridge (N)	42%	- No statistical differences	- No statistical differences	No statistical differences
Slippery When Wet (C) Slippery When Wet (N)	87% 86%	- No statistical differences	- No statistically significant main effect - Sign by group interaction, $p < .01$	No operationally significant differences
Clearance (C) Clearance (N)	90% 71%	- $p > .0001$; N recognized 12% sooner than C	- No statistically significant main effect - Sign by group interaction, $p < .006$ - N significantly slower speed (6%) after recognition, $p < .03$	Lower comprehension offsets performance advantage of N sign

Table 6. Simulator study results—current and new sign comparisons (continued).

Signs Being Compared	Response Accuracy	Recognition Distance (ANOVA)	Speed	Comments
Lane Added (C) Lane Added (N)	10% 10%	- No statistical differences	- No statistical difference between signs main effect - Sign by group interaction $p < .001$	No difference between N and C
Pavement Width Transition (lanes reduced) (C) and (N)	73% (C) 58% (N)	- $p > .018$; N recognized 5% sooner than C	- No statistical differences	Lower comprehension offsets performance advantage of N sign
Yield Ahead (C) Yield Ahead (N)	60% 57%	- No statistical differences	- No statistical differences	No differences between signs
Stop Ahead (C) Stop Ahead (N)	94% 94%	- $p > .037$; C recognized 3% sooner - $p > .003$ interaction; N more consistent across groups	- No statistically significant main effect - Group by sign interaction, $p < .001$ - N sign more consistent	N performed more consistently but C recognized slightly sooner

C = Current sign design
N = New sign design

in the simulator. As table 7 shows, there were no operationally meaningful recognition distance or speed change differences. However, response accuracy or comprehension showed a 22-26 percentage point difference between curve and turn signs.

Further analysis of the response accuracy data (see table 8) suggests that the concept of a sharp turn, portrayed by a right or left 90° angle arrow, is readily understood. The more subtle message of the shallower curve (45°) arrow was lost on 26-29 percent of the drivers. However, the concept of a change in horizontal alignment was not missed, just the degree of that change. Referring again to table 8, notice that only 6-7 percent of the subjects misunderstood both the turn and curve concept.

Looking further at the incorrect responses, table 9 shows that all incorrect responses involved the use of the wrong word to describe the degree of curvature. The concept of change in alignment was present in all cases. This was also true for the few incorrect responses to the turn symbol.

The remaining signs that were tested, cross roads and deer warning, showed no unusual recognition distance or speed response characteristics. Examination of minimum, maximum, and mean recognition distances indicates these signs are within the range of other signs tested. There was also no statistical differences (ANCOVA) in speed between these signs.

The cross roads sign had 100% response accuracy. This was encouraging since the literature review suggested this symbol was not well understood. When placed in a more dynamic driving setting the symbol is apparently well understood. The deer warning symbol, also not as well understood in static tests according to the literature review, appears quite well comprehended as 100 percent of the subjects responded correctly.

Table 7. Simulator study results—curve versus turn signs.

Sign Comparisons	Response Accuracy	Recognition Distance (ANOVA)	Speed (ANOVA)
Right Curve Right Turn	61% 90%	- Because of differences in sign presentation distances statistical results unclear	- No statistical difference pre- and post-sign recognition
Left Curve Left Turn	55% 81%	- No statistical difference between signs - $p > .01$ interaction; left turn distances more consistent across groups	- No statistical difference

Table 8. Comprehension of curve and turn symbols.

Percent	Left Turn	Left Curve	Right Turn	Right Curve
Correct	81%	55%	90%	61%
Incorrect	19%	45%	10%	39%
Both Correct	39%		53%	
Both Incorrect	6%		7%	

Table 9. Analysis of incorrect responses to curve sign.

	Curve Sign "Incorrect" Responses
Right Curve Sign	32% – Called Curve a Turn
	7% – Called Curve a Sharp Turn
Left Curve Sign	36% – Called Curve a Turn
	7% – Called Curve a Sharp Turn
	3% – Called Curve a Sharp Curve

FIELD VERIFICATION

The field verification test was used to verify the recognition distance data and subject responses gathered in the simulator testing. The verification was carried out under controlled field conditions. Once the simulator results were verified in this phase, specific recommendations regarding changes to the MUTCD were made.

Since the field testing was undertaken without the use of an instrumented vehicle, the MOEs gathered in the HYSIM used to examine the curve/turn and advance/crossing problems could not be verified in the field. Therefore, only the Yield Ahead, Stop Ahead, Slippery When Wet, Clearance, Narrow Bridge, Added Lane, and Lane Reduction Transition Sign were field tested.

Test Subjects

A group of 34 subjects was tested. The make-up of the subject group was similar to the simulator subjects. A minimum of five people from each of the age/sex categories was tested. The subjects were identified through a classified ad in a local paper.

Test Procedure

The field test involved measuring subject recognition distances in a static, simulated highway setting under daylight conditions. The subjects were situated in a passenger vehicle on a field test range. The test range was a portion of the unopen section of Maryland State Highway 100. The 13 test signs were displayed on conventional sign posts per MUTCD specifications in terms of height and distance from the roadway. At a starting distance of 854 feet from the sign the experiment was begun. A

movable partition was lowered to allow the subjects to see each sign for five seconds. The subjects were asked to write down what they thought the sign meant. After recording their answers for the first distance, the vehicle was moved to a distance closer to the sign and the procedure was repeated. Besides the starting distance of 854 feet, the signs were also tested at distances of 688, 521, and 309 feet. It was decided to stop at the decision sight distances for speeds of 50, 40, 30, and 20 miles per hour. Since simulated 36-inch-square signs were used in the HYSIM, the distances had to be converted from the actual decision sight distances of 1,025, 825, 625, and 370 feet because 30-inch-square signs were used in the field. Each of the 13 signs was tested at each of the four distances. The order of presentation of the 13 signs at each testing distance was randomly determined.

At the conclusion of the field test, each subject was asked to complete a test booklet similar to the one used in the selection procedure. This was done to have a comparison between the field work and the laboratory studies.

Results

Again, the same numerical coding scheme was used to tabulate the subject responses. In this discussion of the results the signs tested are identified by number. These numbers correspond to the numbers used to identify the signs in the selection procedure. The results of the field test are summarized in table 10. A cursory examination of the table shows extremely low levels of recognition at distances of 688 feet or greater. A look at the results at 521 feet and 309 feet show that many of the signs had small differences between the standard sign and the new candidate. It was decided to examine these results in greater detail.

Table 10. Percentage of subjects correctly identifying the test sign in the field verification test.

SIGN NAME	TEST SIGN #	DISTANCE FROM SIGN (feet) 854	688	521	309	IN BOOKLET
OLD NARROW BRIDGE	40	3%	3%	6%	13%	25%
NEW NARROW BRIDGE	41	9%	9%	13%	18%	81%
OLD LANE REDUCTION	47	38%	50%	72%	75%	81%
NEW LANE REDUCTION	48	40%	25%	47%	69%	63%
OLD STOP AHEAD	49	41%	50%	66%	88%	91%
NEW STOP AHEAD	50	31%	44%	66%	78%	91%
OLD YIELD AHEAD	51	6%	28%	63%	63%	78%
NEW YIELD AHEAD	52	0%	19%	50%	63%	78%
OLD CLEARANCE	53	13%	28%	56%	69%	88%
NEW CLEARANCE	54	0%	0%	0%	31%	97%
OLD SLIPPERY WHEN WET	72	38%	59%	63%	69%	78%
NEW SLIPPERY WHEN WET	73	16%	50%	56%	78%	97%

For the test results at 521 feet and 309 feet a McNemar test of significant change was performed on the data. This test considered the number of test subjects who correctly responded to one of the signs but not the other, and showed that the sign correctly responded to had a greater impact on the subject than the misinterpreted sign. Subjects who got both the old and new sign right or both signs wrong are not considered in the McNemar analysis. The McNemar test then statistically analyzes the distribution of the subjects' answers to determine if the results are significant or are attributable to chance. The results were analyzed at the 0.05 level of significance.

W5-2a Narrow Bridge Sign (Test Signs 40-41). At the longer distances (854 feet and 688 feet) the new sign did slightly better than the old sign, but correct responses were below 10 percent for both signs. The McNemar test for the results at 521 feet and 309 feet were not significant. Again, overall comprehension at these distances was low (less than 19% correct). In the test booklet, however, the new sign was correctly recognized by 81 percent of the test group while the standard sign was recognized by only 25 percent of the subjects.

W4-2 Lane Reduction Transition Sign (Test Signs 47-48). At the first test distance (854 feet) both signs performed about the same, but at 688 feet the standard was recognized twice as often as the candidate sign (50% versus 25%). The McNemar test for the results at 521 feet was significant. At that distance the standard was recognized by 72 percent of the subjects, while the new sign was recognized by 47 percent of the test group. At 309 feet, the McNemar test showed the results to not be significant. The recognition rate at this distance was nearly equal for the old sign and the new sign (75% and 69%, respectively). The test booklet results also showed the standard sign having a superior recognition rate (81% versus 63%).

W3-1a Stop Ahead Sign (Test Signs 49-50). At all four test distances there was very little difference between the performance of the two signs. The McNemar test was not statistically significant for the results at 521 feet or 309 feet. The results from the test booklets were exactly the same (91% correct).

W3-2a Yield Ahead Sign (Test Signs 51-52). The results for these signs parallel the results of the Stop Ahead Sign. Minor differences were seen at each test distance, and both of the near distances had McNemar results which were not statistically significant. The signs were equally well recognized in the test booklets also (78% correct).

W12-2 Clearance Sign (Test Signs 53-54). At the farther distances, the standard sign was not recognized very often by the test subjects. The new sign was not recognized at all. The McNemar test on the results of the sign test at 521 feet was statistically significant. At that distance, the standard was recognized by 56 percent of the test group. The new sign was recognized by none of the subjects. At 309 feet, the standard sign was correctly identified by 69 percent of the subjects, while the new sign was correctly identified by 31 percent of the group. The McNemar test of the results at 309 feet was statistically significant. In the test booklets, the new sign outperformed the old sign by 9 percent (97% versus 88%).

W8-5 Slippery When Wet Sign (Test Signs 72-73). At the first of the four distances (854 feet), the old sign was identified more frequently than the new sign (38% versus 16%). But at the remaining distances the differences in performance were not great. The McNemar tests of the results at both 521 feet and 309 feet were not statistically significant. In the test booklets, however, the new sign was recognized more often than the standard (97% versus 78%).

CHAPTER 6
GUIDELINES, CRITERIA, AND RECOMMENDATIONS

This chapter suggests guidelines to be followed in the design of new signs or the redesign of existing signs. There is also a discussion of methods to be used in assessing the level of comprehension associated with a sign and an examination of criteria to determine "acceptable sign performance." The chapter also includes specific recommendations based on the research results for changes to the MUTCD as well as suggestions for future research.

DESIGN GUIDELINES

The research results from this project have shown that the design of traffic signs is a "no holds barred" proposition. If there is any one guideline to be followed it is that there are no firm guidelines. Some "sure fire" ideas did not work, while the "let's include this one as a lark" ideas often proved to be very valuable. The intuition of a professional designing signs is influenced by many biases. This intuition may not help him understand the motorists' cognitive processes. During this project, the designers/experimenters have seen "good" ideas work for the wrong reasons and bad ideas work for no apparent reason. This does not mean, however, that designers have nothing to aid them when they are designing new signs.

The major need the designer has before begining the design or redesign of a sign is input. This input comes from several sources. First, the designer must have some background in information design principles. This does not mean that he need be an expert in psychology, but he should be aware of the sensory, perceptual, and cognitive aspects of information

acquisition. After the literature search phase of this study was completed, a book was published which provides a very solid base of knowledge about information design. The book, Information Design (Easterby & Zwaga, 1984), is not a "cookbook" for designers. It is, however, a rather complete treatment of the principles on which the state-of-the-art of information design is based. An awareness of the principles covered in this text is a must for sign designers.

Second, the designer must be aware of the "problems" associated with a sign which is to be redesigned or the information requirements necessary to make an effective new sign (newly redesigned or new from scratch). It must be clear to the designer what the miscomprehended meanings of existing problem signs are, and what information is needed to make a new sign work and what information might be superfluous.

Third, the designer must be willing to wholeheartedly accept sign idea input from any available source. Although the designer has specialzed training, he cannot read the minds of motorists. He may generate many ideas which become successful sign designs, but he will also develop some ideas which will not be successful. Therefore, it is thought that there cannot be too many ideas for actual designs, and these ideas can come from any source. Colleagues, other professionals, and the motorists themselves can serve as a source of ideas for sign designs. Based on the results of this project, user input (even if only used to confirm the "good" ideas of the professional designer), must be an integral part of the design process (e.g., Green, 1981).

The essence of communication by sign is the cognitive understanding achieved by those for whom the sign is intended. It is desirable, but not essential, to know how the understanding takes

place. The attitude, "whatever works is best," is perhaps the only "guideline" to be used in sign design, although it may be better stated as, "what works is worth trying."

TEST PROCEDURES AND CRITERIA

Test Procedures

As part of this project many different tests were performed to determine which signs had good cognitive value. During the laboratory, simulator, and field phases it was learned which of the tests were the most effective. Based on those experiences the following test scheme is suggested.

A two phase test procedure should be used. It would consist of a paper-and-pencil laboratory test procedure as well as a field test procedure described under "Candidate Selection" in chapter 5 of this report. The paper-and-pencil testing and follow-up debriefing proved to be a quick and economical way to get a lot of information about candidate signs. It is suggested that the procedure be kept the same, and that the selection and number of test subjects be kept the same also. State motor vehicle administration offices proved to be a good place for finding a wide socio-economic spectrum of licensed drivers with time on their hands. It is suggested that this practice be retained as well.

The field test procedure would be different from the HYSIM and field test procedures used in this study. Although the experiments designed for both of these procedures were well thought out, the results frequently failed to discriminate between old and new signs from a legibility standpoint. The test procedures did raise some interesting points, however. While the new signs often did not perform better than existing

signs, they did not perform any worse in many situations. The results of the field test show that many of the signs, both old and new, were not visible/understood until the subjects were at a distance which corresponds to the decision sight distance for a running speed of 20 miles per hour (309 feet). While this might lead one to believe that such signs are inadequate to warn of hazards on roads where the running speeds are above 20 miles per hour, it must be remembered that the signs themselves are not placed at the actual hazard, but at a distance which is well in advance of the hazard. These distances are usually based on the decision sight distance model. Therefore, it is not necessary that the signs be legible/understandable hundreds of feet away. It is imperative, however, that the motorist receives (can see) the information and processes (understands) it before he passes the sign location. At that point the decision sight distance space is being used and there is not time (distance) for information reception and processing. A more accurate field test would be one where the sign's ability to communicate is assessed before the sign is passed.

Based on the research results and the experience of the project team in the simulator and field tests, the following test scenario is suggested. On a straight section of highway the test sign is placed according to MUTCD specifications. The test subject would be the driver of the test vehicle. The vehicle could be a standard passenger automobile. At a distance of 2000 feet from the sign, the test would begin. The subject would be asked to accelerate to the test speed. The test speed would be a predetermined speed based on the average running speed for the type of road on which the sign would be used most frequently. For example, when testing a sign such as the Merge Sign (W4-1), which is used on higher speed facilities, the test speed might be 55 miles per hour. If a sign such as School Bus

Stop Ahead (S3-1), which is used on roads with lower speeds, is tested then the test speed might be 35 or 40 miles per hour. The size of the sign used would be predicated on type of facility simulated as well. Once the test speed is reached, the subject would be asked to hold the car at that speed until he has passed the sign. When the sign is passed the experimenter will ask the subject to tell what the sign means. The experimenter will record the subjects' answer verbatim, and if the answer seems unclear the experimenter will use the debriefing questions used in the paper-and-pencil testing. This procedure simulates the conditions under which the driver would be gathering information from the sign. The driver can receive and process information until the sign is passed while having the task of maintaining the vehicle at the test speed.

It is believed that the use of the paper-and-pencil testing to determine the cognitive potential of each sign candidate and field testing the most promising signs under conditions which simulate the actual driving situation is the best method for testing sign designs.

Test Criteria

As was discussed in chapter 3 of this report, "Criteria for Motorists' Sign Comprehension," it is very difficult to come up with a precise percentage of correct performance to define the point at which a sign is considered useful. Whatever sign performs the best should be the one which is used, regardless of the percentage of correct responses. A sign that warns 59 percent of the motorists about a hazard is better than no sign at all. However, a 90 percent comprehension level or greater is not unrealistic since many of the signs, old and new, tested in this project did achieve that level. While some groups have set minimum critieria (e.g., 85% by the Standards Association of

Austrialia (SAA) and 66% by the International Standard Organization (ISO) for travel information signs), these numbers appear to have no empirical basis. Therefore, it is suggested that the sign which performs the best in the field test be used as the new sign. It is also suggested that more research be done examining the establishment of a minimum percentage criterion for comprehension of a sign. Until a minimum percentage value is established, it may be prudent to have a policy of using the SAA or ISO values.

RECOMMENDATIONS

This section makes recommendations regarding the problem signs studied in this project. In some cases, the research served only to pose more questions. In other cases some additional work may be warranted. In still other cases, a strong argument can be made that a current MUTCD sign should be replaced with a candidate developed in this study. A discussion of specific signs follows. The signs are referenced by the identification numbers used in appendix I.

The "Curve" Family of Signs (Test Signs 1-16). Based on the results of the selection procedure and HYSIM study, there is a lack of consensus about whether these signs have any problems at all, if there are too many signs in this group, or if even more signs are needed.

The use of the words "curve" and "turn" interchangeably by test subjects has caused much confusion about interpreting results. It appears that the terms "curve" and "turn" mean the same thing to most motorists. The degree of curvature which makes a "curve," a curve and a "turn," a turn is noted by the motorist through the use of an adjective such as sharp, hard, or easy. When shown a

curve and turn sign together most drivers will note a difference between the two, but whether that difference is retained for later comparison to these signs individually was not determined. It was hoped that the tracking and speed profiles of subjects tested in the HYSIM would yield some information about the driving behavior differences when encountering a curve or turn sign. There were no significant results from that testing.

The results with the reverse curve and reverse turn were the same as with the curve and turn. There was no consistency in terminology, and, therefore, it was difficult to tell if there was an understanding difference between these two signs. The debriefing results for these signs showed that the number of curves expected by motorists varied from "one" to "many." The driver had the same problem, knowing the number of curves to expect, with the winding road sign as well. It seems fairly certain that most motorists can tell the difference between a sign that warns about one curve/turn and a sign that warns about multiple curves/turns.

The direction of the curve/turn is usually known by motorists who see a design depicting a single curve/turn, but many motorists had trouble picking out the direction of the first curve on the winding road sign.

Although much new information about motorists' interpretation of these signs was uncovered, it appears that this is an area in which some additional research needs to be done.

The "Crossing" Family of Signs (Test Signs 17-23, 27-31). The advance/locator concept of a pair of signs such as the stop ahead and stop signs seems very well understood by the motoring public. This same concept when used to warn of a crossing ahead,

and then to indicate the location of the actual crossing is not at all understood by motorists. While it might appear that the crossing location signs were correctly identified more often than the advance signs, this is not the case. The test subjects initial response to all of these signs is "crossing," with the words pedestrian or school usually added where appropriate. This suggests that the advance signs perform poorly, and that the crossing signs do better. During the debriefing sessions, however, when asked about the significance of the arrows on the advance signs, most subjects would casually reply, "Ahead." They would often go on to remark that all the signs they had seen in their booklet meant ahead. Even though their written replies made it appear as if the crossing signs were understood better than the advance signs, the opposite was actually true.

Many subjects had difficulty distinguishing between adult and school children pedestrian figures. The problem was greater with the figures on the standard sign, but it existed for the new figures used on the school signs as well. The very young children figures developed for the first testing phase were usually recognized as children, but they were seldom associated with a school. More often, the young children figures evoked comments about playing in the streets or playground areas.

As with the "curve" family, much new information has been gained about these signs, but it appears that additional study is warranted.

School Bus Stop Ahead Sign (Test Signs 24-26). It appears as if the existing sign does not present much of a problem, but the laboratory did produce two viable symbolic alternatives for this existing worded message. Given the language, literacy, and quick recognition advantages of symbolic

signs and the fact that a variant of these signs is already used in Canada, it is recommended that either Sign #25 or Sign #26 be included in the MUTCD as a symbolic alternative for the existing sign S3-1.

Pavement Ends Sign (Test Signs 32-34). Although Sign #34 did outperform the standard by 10 percent in the laboratory, these results were not considered significant enough to warrant field testing and replacement of the standard.

The Low Shoulder/Uneven Pavement Family of Signs (Test Signs 35-39). Both of the standard signs from this group performed poorly in both laboratory experiments. The problem, as noted in the problem identification phase of the project, is that they are often confused with each other. While the symbol version of the Uneven Pavement sign (#37) has not been officially adopted for the MUTCD, it is in use by some of the Western States in the United States. It appears that all of the candidate signs are an improvement over the existing versions. Since Sign #39 uses two vehicles in its depiction of uneven pavement, Sign #39 has a greater visual difference from Sign #36, the low shoulder candidate, than Sign #38, the other uneven pavement candidate. In order to not duplicate the current problem of having the symbols for these signs look too much alike, it is recommended that Sign #36 and Sign #39 be retained for future testing and possible inclusion in the MUTCD.

Narrow Bridge Sign (Test Signs 40-43). The idea to show the bridge symbol crossing over something to make it look more like a bridge was a good one. Showing the bridge crossing over representations of water and a highway improved the comprehension level of the sign by drivers. The symbol depicting the bridge crossing railroad tracks was not very successful. The sign was often confused for one warning of an at-grade rail crossing.

Even the bridge over the highway symbol was sometimes confused with a sign warning of the intersection of two roads. It was felt that a bridge crossing water was a population stereotype of bridges in general, and it is not necessary that the motorist knows what the narrow bridge is crossing as long as he knows that it is a narrow bridge. When field tested against the standard, Sign #41 performed better. Therefore, it is recommended that Sign #41 be adopted as the symbol version of the narrow bridge sign in the MUTCD.

One Lane Road Ahead Sign (Test Signs 44-46). This sign appears to have fewer problems than originally thought, but this was realized only after the debriefing sessions in the selection procedure. While few motorists could give a correct written explanation of two-way operations over a one lane section of road, most gave an acceptable verbal description. The laboratory procedures did produce two viable symbolic versions of this sign. Given the language, literacy, and quick recognition advantages of symbolic signs, it is recommended that either Sign #45 or Sign #46 undergo field testing for possible inclusion as the symbolic version of this sign in the MUTCD.

Lane Reduction Transition Sign (Test Signs 47-48). The major problem with this sign is that the use of the wide black borders confuses some motorists so that they think the black bars are representations of the road (as with the curve sign, where the black band tail of the arrow represents the road, not the road's edge). Many motorists think the bar on the right is their side of the road and the road is going to curve to the left. It was expected that the addition of pavement marking to the sign would help this problem, and the additional problem of some motorists who see the sign as a narrowing of the road, but not necessarily as a lane reduction. This was not the case, however, as many drivers interpreted the pavement marking lines

as the end of an acceleration lane onto a highway. Overall, the standard did not perform badly, but the amount and types of confusions associated with the standard do suggest some additional study.

Stop Ahead/Yield Ahead Family of Signs (Test Signs 49-52). The major problems expected from these signs at the start of this project was possible confusion with the actual stop or yield signs, and confusion of the ahead arrow as an indication of roadway alignment. There were some instances where these wrong interpretations were made, but not often enough to be considered a problem. The major problem was motorists' inability to identify the triangular part of Sign #51 and Sign #52 as a yield sign. This may be due to the fact that many motorists expect the yield sign to look like the pre-1971 version of that sign.

These signs became a test case for placement of the ahead arrow on a warning sign. In the first laboratory study the yield ahead sign was identified correctly much more often when the ahead arrow was placed on the bottom of the sign. The stop ahead sign had a similar result, but not a statistically significant one. In the second laboratory phase the trend of the arrow on the bottom evoking a better response held for all signs where it was used except the school bus stop ahead sign. Each individual experiment did not have statistically significant results, but the trend did seem to favor the arrow placement on the bottom. The field test results showed no significant trend one way or the other. One possible explanation is that the directional arrows used with trailblazers and route markers are placed below those signs and motorists have become familiar with this usage, which predates the use of arrows on symbol signs.

As motorists become familiar with the present configuration of the yield sign, the comprehension level of the yield ahead sign should approach that of the stop ahead. Though the placement of the ahead arrow appears to be a statistically moot point, this question may merit some further study.

Clearance Sign (Test Signs 53-55). The standard sign performed significantly worse than the two candidate signs in the first laboratory procedure. In the second laboratory phase, all three signs were recognized by more than 90 percent of the test subjects.

In the field test the standard was compared to Sign #54. Sign #54 was used because it was felt it would be more visible than Sign #55. There was a need to see if signs with large amounts of black area, such as Signs #34, #36, #54, #55, #65, and #71 would pose visiblity problems for motorists. Since Signs #53 and #54 had nearly equal laboratory test results, it was thought that the field results would be a test of visibility and not comprehension. The field results showed that the standard significantly outperformed Sign #54, and it was evident that comprehension was not a problem because Sign #54 outperformed the standard in the laboratory test booklets completed by the field test subjects. Therefore, it is recommended that the standard sign be retained. It is also recommended that further field testing be done on the "black area" sign types using the revised field procedures outlined in this chapter.

End Divided Highway Sign (Test Signs 56-58). This sign had the highest severity ranking of all the signs studied in this project. An attempt was made to address the directionality problem associated with this sign, but many subjects confused this sign with its counterpart, the begin divided highway sign.

The candidate signs did not do as well as the standard, but the standard did not do very well either. In the first phase of laboratory testing, 64 percent of the subjects did not know what this sign meant. In the second phase, 29 percent could not identify this sign. A sign with such important safety implications should be understood by nearly all motorists, therefore it is recommended that additional work be done, either through sign design or driver education, to increase the level of comprehension associated with this sign.

Two-Way Left Turn Only Sign (Test Signs 59-60). In both laboratory tests there was no statistical significance in the results, but in both tests the new candidate sign did outperform the standard. In the debriefing sessions it became clear that a driver's familiarity with the two-way left turning concept was most often responsible for his recognition of the sign. The driver to whom the concept was totally foreign could not even give an answer which was close to the intended meaning. Therefore, it would seem that increased educational efforts about the concept, and not a change in the sign design, would help the situation the most.

Keep Right Sign (Test Signs 61-62). The signs in this group are most often confused with the end/begin divided highway signs. It appears that drivers are unaware of the concept of having markers or signs delineate the location of fixed objects such as curb noses. Therefore, it is recommended that the standard sign be retained and some examination of the educational needs of drivers regarding this sign be undertaken.

The Merge/Added Lane Family of Signs (Test Signs 63-65). The merge sign was very well understood in both laboratory tests. The added lane signs (#64 and #65) did very poorly in both phases

of laboratory testing. The added lane signs were frequently identified as merge signs. There is no difference between these two types of sign in the minds of most motorists. They are all interpreted as a merge sign. It seems that the concept of a merge with an added lane is not known to drivers. Therefore, it is recommended that some work be done on educating motorists that the two distinct concepts of merging and merging with an added lane do exist, or the added lane sign should be dropped from the MUTCD.

The Flagger/Worker Family of Signs (Test Signs 66-69). For both of these signs the new candidate signs outperformed the standard signs in both laboratory tests. It was noted that both of the improved designs had a similarity in overall composition to their corresponding problem sign, and the added cues to the signs' meaning were taken from enhancement of detail in the sign (e.g., making the "worker" and his "work" in the worker sign look a little less abstract and a little more real world). Therefore, since both of these new signs had the same long distance appearance as the signs they would replace, it was decided not to field test the designs. It may be necessary to field test them according to the new field test procedure which has been proposed in this chapter. It is recommended that the new signs replace the existing signs in the MUTCD.

Hill Sign (Test Signs 70-71). The results for both the standard sign and the new candidate showed that both signs performed very well (greater than 90% correct). In coding the results, any subject response containing the word "hill" was considered right, but in the problem identification phase it was noted that very often this warning is thought to only apply to trucks and other large vehicles. At times the warning may be germaine to both trucks and cars; therefore, a sign which gives motorists the idea only large vehicles need to heed the sign's

warning may not be a useful sign. If the right answers where a truck is mentioned were eliminated from the right answer totals, then the standard (#70) was correctly recognized by only 50 percent of the test subjects. The new sign (#71) was correctly identified by 92 percent of the test group. The MUTCD makes no mention of the fact that this sign is intended only for large vehicles and not passenger automobles. If it is desired to have a sign which warns all drivers about a hazardous hill, it is recommended that Sign #71 replace the standard in the MUTCD.

Slippery When Wet Sign (Test Signs 72-73). In the first phase of laboratory testing, the new candidate sign did significantly better than the standard sign. In the second laboratory testing phase the new sign performed better again, but not as well as in the first phase. The field testing showed the new sign as superior again, but the statistical results were not significant. Since the design changes on the new sign (the horizon line and raindrops) do not significantly change the overall appearance of the sign and the results show the sign to have mildly positive to very positive affects, it is recommended that Sign #73 be adopted as the new standard in the MUTCD.

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